How should root filled posterior teeth be restored? A systematic review and survey to general dental practitioners

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Abstract

Restoration of the root-filled posterior tooth: A systematic review and survey to general dental practitioners

Introduction

The restoration of the root filled posterior tooth has been a controversial topic with conflicting evidence. There is also limited information of how general dental practitioners (GDPs) restore root-filled posterior teeth in the United Kingdom. The aims of this thesis were, to investigate the relative effectiveness of direct and indirect coronal restorations, without posts, for the restoration of root-filled posterior teeth and to investigate the decision-making and perceptions of GDPs when restoring root filled posterior teeth.

Methodology:

This thesis consisted of a systematic review and a vignette-based survey. For the systematic review, MEDLINE, PubMed, EMBASE, Scopus, Web of Science and Central databases were searched from inception to December 2019. Randomised and non-randomised studies in which adults with root-filled molar and premolars were treated with either direct restorations or indirect restorations without posts were included. Studies with subgroups of patients who had restorations with posts in any arm were included. Studies where bridge retainers or partial dentures were used, studies in which teeth were periodontally compromised and studies in which all teeth were treated with posts were excluded. Key outcomes were clinical and radiographical failure of the restoration. We used the

Down's and Black quality assessment checklist to assess the quality of the included studies.

For the second study, an online survey comprised three clinical vignettes was designed and distributed to GDPs in the United Kingdom. The survey asked questions to the GDPs about where they work, experience and current practice. The vignettes were clinical scenarios of root filled posterior teeth, which showed a picture of the tooth and questions related to how the GDP would restore that tooth and the factors that may influence their decisions to restore the tooth. The survey was piloted amongst a small number of GDPs before being distributed and ethical approval was obtained from the University of Liverpool research and ethic committee. The answers were analysed quantitatively and descriptively.

Results:

The searches for the systematic review study identified 10,166 non-duplicate articles and the study inclusion criteria were applied to 121 articles. There were 12 studies (6 comparative and 6 non-comparative) in the narrative review. The majority of the studies were of poor to fair quality and the heterogenous nature of the studies precluded statistical data synthesis. One retrospective study compared direct versus indirect restorations for root-filled posterior teeth without posts; however, the strength of the study results was limited owing to the low number of patients in the indirect restoration group (partial gold crown, n=24) compared with the direct restoration group (glass ionomer, n=100; amalgam, n=98 and composite, n=37).

A total of 528 GDPs completed the online survey in 2018/2019 over a period of four months. Indirect restorations were the most common type of restoration chosen for posterior root-filled teeth regardless of the amount of tooth structure remaining. Confidence of GDPs increased with increased years of experience, P value was significant.

Conclusions:

The systematic review showed that there was limited evidence to suggest that direct restorations were more effective than indirect restorations (or vice versa) in root-filled posterior teeth without posts.

GDPs vary in their approach to restoring root-filled posterior teeth. Training, financial, patient factors and tooth factors are important to GDPs when restoring root-filled teeth.

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Chapter 1

1.1 Introduction

Endodontics is a speciality within dentistry that focuses on diagnosis, management and treatment of the nerves and blood vessels of the tooth known as the dental pulp. Teeth can undergo damage, more commonly through decay and traumatic injuries. The ingress of microorganisms into the dental pulp can damage the pulp incurring infection and subsequently the pulp can lose its blood supply known as pulp necrosis (Kakehashi, Stanley and Fitzgerald, 1965). Microorganisms have been identified as the cause of root canal infection by releasing toxins into the peri-radicular tissues (Kakehashi, Stanley and Fitzgerald, 1965), forming chronic periapical periodontitis (Nair *et al.*, 1990; Sundqvist *et al.*, 1998). The by-products and the toxins lead to the formation of pain, inflammation and swelling (Zehnder, Gold and Hasselgren, 2002).

Root canal treatment is the treatment of choice if the tooth is to be maintained and is less invasive than extracting the tooth. Success of root canal treatment has been shown to be high in the literature (Salehrabi and Rotstein, 2004; Pirani *et al.*, 2015).

Root canal treatment reduces proprioceptive tooth protection during chewing as a result to removal of the nerve content of the tooth (Randow and Glantz, 1986). These non-vital teeth are more vulnerable and are exposed to higher occlusal forces compared to vital teeth (Sedgley and Messer, 1992).

Root-filled teeth have generally lost more coronal tooth structure due to caries, fracture and tooth preparation to perform root canal treatment, which reduces the amount of tooth structure further. Assessment of the quantity and quality of the remaining tooth structure needs to be carefully considered in order to restore the root-filled tooth (Torbjörner A, 2004). A final restoration must provide a good coronal seal and protect the remaining dental tissue, as well as restore form and aesthetic and occlusal function (Aquilino and Caplan, 2002). Definitive restoration of the root-filled tooth can be done with a direct or indirect restoration both of which have shown to be successful when compared to temporary materials (Nagasiri and Chitmongkolsuk, 2005). The importance of coronal coverage has been well reported in the literature (Salehrabi and Rotstein, 2004),

Which restoration type direct or indirect to restore the root-filled tooth can be a difficult decision for the clinician. Traditionally crowns have been advocated as necessary to provide protection in order to ensure clinical success of the root-filled tooth (Sorensen and Martinoff, 1984). Crowns are more expensive to provide and remove more tooth structure on preparation, subsequently weakening the core of the tooth.

Two systematic reviews assessed crowns versus direct restorations for restoring root filled posterior teeth (Stavropoulou and Koidis, 2007; Fedorowicz *et al.*, 2015). One review (Stavropoulou and Koidis, 2007), concluded that crowns had more success over direct restorations, 81% and 63% respectively. Whereas, the other review (Fedorowicz *et al.*, 2015), found limited evidence to recommend a direct restoration over an indirect restoration. In clinical practice it seems that each tooth's condition should

be evaluated individually, and advantages and disadvantages of all restorative possibilities should be assessed.

Chapter 2

Literature review

2.1 Introduction

The dental specialty of Endodontics focuses on the management of the dental pulp. Microbes from the oral microflora may infect teeth and their supporting tissues. This can be caused by a number of factors such as dental caries, trauma to the teeth caused by an injury, fractures, gaps and cracks in teeth, restorations and tooth surface loss. Once microorganisms become present in the root canal system and dentinal tubules they release toxins, which form an apical inflammatory lesion known as Apical Periodontitits (AP), (Kakehashi, Stanley and Fitzgerald, 1965; Van Hassel, 1971). Toxins are by-products released from microorganisms which can eventually stimulate a chronic inflammatory reaction in the host leading to pain and swelling (Zehnder, Gold and Hasselgren, 2002).

Once it has been determined that the pulp is necrotic or irreversibly inflamed the treatment options for the patient are as follows

1. Root canal treatment and restoration of the tooth.
2. Extract the tooth
3. No treatment and to observe and review the tooth. This option has the risk of pain and infection developing.

Root canal treatment or endodontic treatment is a procedure that involves removal of the dental pulp, which is then replaced by a root filling material (Heydecke and Peters, 2002).

This is achieved by disinfecting the root canal system.

Chemo-mechanical preparation of the root canal system is also known as root canal disinfection. This procedure uses antimicrobial irrigants, the most common being sodium hypochlorite and small instruments (endodontic files). Together, help shape the root canal system by enlarging the canal space, allowing sodium hypochlorite to penetrate deeper into the apical areas (Hulsmann, Peters and Dummer, 2005).The root canals are then obturated, to provide an apical seal to prevent reintroduction of bacteria into the canals (Sjögren *et al.*, 1990). An effective obturation provides an apical and coronal seal, and acts to entomb any remaining bacteria (Ray and Trope, 1995).

Success of conventional root canal treatment has been reported to range from 40% to 97% depending on study design, clinical procedures, criteria for evaluation and length of the observation period (Sjögren *et al.*, 1990; Smith, Setchell and Hary, 1993). However, these results are only promising if the tooth has received an appropriate coronal restoration after the completion of root canal treatment. The coronal restoration ensures longevity of the root filled tooth (Stavropoulou and Koidis, 2007).The management of the patient continues after the completion of endodontic treatment. The root filled tooth has to be restored to form and function.

2.2 Effects of endodontic treatment on the tooth

Root treated teeth show changes in neuro-receptive and biomechanical behaviours especially when compared with teeth possessing vital pulps. Dehydration, demineralisation, collagen alteration and reduction of

proprioception can occur with the loss of pulp tissue (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini, Berutti, *et al.*, 2015).Sodium hypochlorite (NaOCl) and chelators such as Ethlyenediamine Tetra-Acetic Acid (EDTA) and calcium hydroxide are commonly used for root canal disinfection. These products, however, can interact with root dentine. Chelators such as EDTA can cause dentine erosion and softening. Chelators cause calcium depletion and can alter the effect of non-collagenous proteins. These interactions reduce the elasticity of dentine and its flexural strength to quite some extent. It is therefore possible that there is a decrease in dentine strength due to the effects of endodontic irrigants (Cohen, S. and Hargreaves, 2006).

It is also important to be aware that the changes that occur in the dentine of endodontically treated teeth can affect its function under mechanical stress (Sedgley and Messer, 1992). Sedgley et al showed that vital dentine was much harder than the dentine found in contralateral endodontically treated teeth. This was shown in vitro with matched teeth pairs. However, the thought that endodontically treated teeth were more brittle was not supported as the results showed no significant biomechanical change in the teeth (Sedgley and Messer, 1992). These findings were supported by Papa et al, who also showed no significant difference in the moisture content of vital and endodontically treated teeth (Papa, Cain and Messer, 1994).

Endodontically treated teeth have been observed to experience a higher number of crown/root fractures compared with vital teeth that have similar coronal restorations (Gutmann, 1992). It is thought that the remaining

amount of tooth structure influences the ability of the tooth to withstand mechanical forces A conservative endodontic access preparation involves the loss of tooth structure that reduces tooth stiffness by around 5% (Trope and Ray, 1992). Tooth stiffness is further compromised when additional tooth preparations are carried out, such as the loss of marginal ridges. The extent of reduction of stiffness on the tooth have been reported to be between 20%-63% for occlusal cavity preparation and between 14%-44% for MOD cavity preparation (Larson TD, Douglas WH, 1981; Reeh, Messer and Douglas, 1989; Vanherle, 1995).

It is apparent that the strongest tooth is one that retains the most sound dentine and enamel on which to rebuild the tooth to form and function. The preparation of a post space (cast or fibre) has been shown to significantly weaken the root-treated tooth (Ikram *et al.*, 2009).

Apart from reduction of tooth stiffness endodontic treatment also affects the aesthetics of the root-treated tooth. Colour change and darkening of the tooth following root canal treatment is a common observation. During the cleaning and shaping process necrotic pulp tissue can be left behind which can result in the tooth darkening. Other contributory factors are root filling materials, products of haemoglobin, and penetration of food and drink (Cohen, S. and Hargreaves, 2006). The darkening of the tooth can affect the decisions made on restoring the tooth after root canal treatment.

2.3 Success and survival of endodontic treatment

Success rates for non-surgical root canal treatment range from 40% to 97%. This variation depends on the type of study design, clinical

procedure, how success is evaluated and the length of the observation period (Stavropoulou and Koidis, 2007).

Traditionally success of root canal treatment has been assessed clinically, radiographically and histologically (Estrela *et al.*, 2014). Abbott et al, described endodontic success histologically by the complete repair of the periapical tissues without presence of inflammatory cells (Abbott ., 1991). Few studies have used histopathological examination to assess endodontic success. It is unethical to obtain periapical sample tissues from humans unless there is a clinical need and therefore, clinical and radiological examinations are the most common used methods to evaluate endodontic outcome.

The placement of a coronal restoration on a root filled tooth has shown to influence the endodontic outcome (Ng, Mann and Gulabivala, 2011). A study showed teeth that had a satisfactory coronal restoration showed better periapical healing compared with teeth that had unsatisfactory restorations, where satisfactory restorations had no discolouration, no marginal discrepancy, or recurrent caries with no history of decementation (Niederman and Theodosopoulou, 2003; Ricucci *et al.*, 2011).

The counter argument is that some studies have found there to be little difference in endodontic outcome when root filled teeth were restored with permanent restoration (Chugal, Clive and Spångberg, 2007; Ng, Mann and Gulabivala, 2011). The type of permanent restoration also had little significant influence on the outcome of endodontic treatment (Sjögren *et al.*, 1990; Ng, Mann and Gulabivala, 2011).

The ESE (European Society of Endodontics) guidelines advise the placement of an adequate restoration after root canal treatment. This is to prevent the recontamination of microbes. Therefore, a coronal restoration of any type but of good quality should be provided to teeth post endodontic treatment (Löst, 2006).

Dental implants, which are an alternative treatment option to root canal treatment, have in the literature shown high probability of survival. This treatment compared with root canal treatment and has led to an increase in elective extractions in order to provide dental implants (Ng *et al.*, 2008). The most commonly adopted measure of successful implant treatment has been survival of the implant fixture, the survival and associated complications of implant-retained restorations have been less frequently considered (Creugers *et al.*, 2000).

When reviewing the literature on the success of non-surgical root canal treatment, it quickly becomes apparent that outcome definitions and classification have been inconsistent resulting in considerable variability of the reported 'success' rates. The American Association of Endodontists have adopted alternative definitions of success for endodontic treatment, namely, functional survival of the tooth (Friedman and Mor, 2004). This evaluation method not only eliminates the tremendous subjectivity involved in trying to assess success and failure, but also makes way for a fairer comparison with dental implants, as the latter tend to adopt survival rather than success criteria as an outcome measure of treatment.

A number of studies (Hargreaves, 2001; Caplan *et al.*, 2002; Salehrabi and Rotstein, 2004) have reported on the survival of teeth (time to extraction)

after root canal treatment. Survival of root filled teeth was found to improve by the placement of crowns and cast restorations. A systematic review showed that root filled teeth with crowns survived better than those without crowns. Teeth without crowns seemed to survive well up to the first three years then this survival rate declined (Stavropoulou and Koidis, 2007). However, a randomised control trial found the opposite with equal survival rate between conventional composite fillings and crowns (Mannocci *et al.*, 2002). The studies included in the systematic review didn't specify which type of restorations were utilised, for example type of indirect or direct restoration, also there was a lot of bias from the included studies. The lack of sample size calculation especially with the randomised control trial reduced its reliability.

It is therefore important to adequately assess the prognosis of the tooth as failure to do so could result in a higher number of extracted teeth (Smith, Setchell and Hary, 1993).

2.5 Restorability of the tooth

The assessment of restorability of the tooth should be undertaken before endodontic treatment is started. This assessment should be a part of the general restorative treatment plan. The endodontically treated tooth due to the sheer nature of previous restorative and endodontic treatment tends to lack sufficient tooth structure. Therefore an adequate amount of remaining tooth structure is required to restore the tooth to full form and function (Sorensen and Martinoff, 1984).

Tjan and Whang (Tjan and Whang, 1985), observed in vitro that 1mm of root wall thickness, which were loaded horizontally, had a higher chance

of fracture compared to roots with thicker walls. Sorensen and Engleman 1990 (Sorensen and Engelman, 1990), looked at the effect of maintaining coronal tooth structure in vitro. Different types of ferrule designs were examined in order to investigate the resistance to fracture of root filled teeth. Using parallel-sided walls above the finish line of the preparation creates the ferrule. Also, more conventionally by an encircling band of metal as part of the post and core, or crown. The conclusions drawn were that 1mm of coronal dentine present above the finish line significantly increased fracture resistance. Al-Wahadni and Gutteridge recommend maintaining 3 mm of tooth structure (Al-Wahadni and Gutteridge, 2002). These studies looked at single rooted teeth. How the ferrule effect influences molar teeth has little evidence. The tooth restorability index (TRI) has been developed to aid the clinician in assessing how restorable a tooth is. This is a structured assessment using specific parameters to determine remaining coronal tooth tissue (McDonald and Setchell, 2005).

In the absence of sufficient coronal tooth tissue, surgical crown lengthening procedures should be considered. This should be assessed with a detailed periodontal examination initially. A periapical radiograph should be used to assess, the length of the root, the crown: root ratio, furcation location, and the taper of the roots. The root of the tooth should be long enough that once bone removal is done the crown to root ratio isn't compromised. Orthodontic extrusion can also increase the crown height and is an alternative method of gaining more coronal tooth structure (McDonald and Setchell, 2005).

2.6 When to place the definitive restoration?

The decision whether to place a definitive restoration immediately after root canal treatment can be difficult. This is usually because of uncertainty of the success of the root canal treatment. Root canal treatment can take up to one year and sometimes up to four years for a periapical lesion to heal. It is not always practical or acceptable to the patient to wait such a long time to place a definitive restoration. There are no set rules, but the following factors are generally taken into consideration.

- Pre-existing endodontic status
- Quality of the root canal filling
- Position of the tooth in the mouth
- The type of restoration planned.

As the mean success rate for root canal treatment is relatively high around 85%. The clinician has to wonder if the tooth in question is one of the 15% that aren't successful (Cohen, S. and Hargreaves, 2006).

Factors such as lack of patency during treatment, large periapical lesions, periodontal involvement, extruded root canal material, root resorption, and persistent signs and symptoms, may indicate that treatment is more likely to be unsuccessful (Ng, Mann and Gulabivala, 2011).

A period of review is usually advisable for a one-month period prior to providing the permanent restoration. This is useful as a small number of teeth without symptoms may be missed and may fail (Cohen, S. and Hargreaves, 2006).

If the clinician chooses to wait for radiological evidence of healing, which is recommended to be checked annually and then up to four years after root canal treatment (Löst, 2006), then the tooth's remaining tooth structure should be protected to prevent tooth or root fracture. An appropriate interim restoration should be chosen which prevents coronal leakage and if cuspal coverage is planned in the final restoration then the placement of an orthodontic band would be advised in order to counter cuspal or coronal fracture (Forde, 2011).

A recent study into the timing of placement of a crown on root filled teeth showed that the survival of the root filled tooth benefited from earlier placement of the crown, which was suggested to be within four months (Pratt *et al.*, 2016) . However, This was a retrospective study where there was no mention of the quality of the root canal treatment, the amount of remaining tooth structure, also of the teeth that were extracted it wasn't clear exactly why they were extracted and the information given was that any tooth that had fractured was extracted. The results of this study were interesting; however, they can't be extrapolated to a general practice situation and without more information about the variable factors it is difficult to make clear conclusions. To the author's knowledge, there was no information in the available literature, about when teeth are being restored following completion of root canal treatment in general dental practice in the U.K. The dilemma of whether to place a permanent restoration immediately after completion of the root canal treatment or to delay the restoration until healing of the apical periodontitis is present among dentists (Schwartz and Robbins, 2004). A study looked at the effect

of delaying permanent coronal restoration on the prognosis of root filled teeth. The results showed a slightly better resolution of periapical radiolucency when permanent restorations had been placed (amalgam, composite and crowns) than those receiving temporary restorations (IRM and Cavit) (Safavi, Dowden and Langeland, 1987). Although the results showed no statistically significant difference between the two groups this could have been due to the small sample size and other factors such as a high number of anterior teeth that were included in the study.

2.7 How to restore teeth after endodontic treatment

The aim of restoring the root filled tooth is to achieve good aesthetics, form and function by preserving as much healthy tooth structure as possible (Cohen, S. and Hargreaves, 2006).

There will be some patients who will want to save their tooth at almost any cost, even if the prognosis is guarded. Others may not wish to have complex treatment and only have predictable options.

The type of restoration for the root filled tooth is dependent on the amount of tooth structure remaining as well as aesthetics and functional requirements.

Anterior and posterior teeth have different biomechanics and restorative demands.

The functions of anterior teeth are to incise and tear. They act as guiding surfaces for mandibular excursions in parafunction. The loading of anterior teeth tends not to be axial unless in class 3 malocclusions. In the

labiobuccal plane anterior teeth are broader, this is to provide greater bulk and strength in the labiobuccal-loading plane (Cohen, S. and Hargreaves, 2006).

The functions of posterior teeth are to serve a grinding, crushing function. They have a broad rectangular base with multiple broad roots buccolingually. Axial loading is the main type of loading for posterior teeth except in mandibular excursive movements. During these movements' forces can jar teeth, which are in interference. These interfering contacts cause cracks and fractures to occur on posterior teeth (Cohen, S. and Hargreaves, 2006).

Anterior and posterior teeth require separate considerations when planning the restorative phase of treatment as a result of their varying structures and forces on loading (Eliyas, Jalili and Martin, 2015).

There are two methods of restoring the functional and aesthetics of the root filled tooth.

1. The direct approach
2. The indirect approach.

The direct method is a conventional technique in which the dentist places a restorative material such as amalgam, composite or glass Ionomer directly into the tooth. This way of restoring the tooth usually simpler than the indirect method and takes one visit. They have been shown to have good survival characteristics also (Bjertness and Sønju, 1990; da Rosa Rodolpho *et al.*, 2006).

Examples of the indirect method include, crowns, inlays, onlays and so called ‘endocrowns’. The indirect restorations are constructed with materials such as composites, cast metal or ceramics such as porcelain. Indirect restorations are usually more costly to the patient as a result of the need for impression taking and laboratory costs.

Posts can be used in either direct or indirect approach. Posts are placed into the root canal to provide increased retention for the restoration, be it either direct or indirect (Bolla *et al.*, 2016).

2.8 Restorations

2.8.1 Direct composite restorations

After endodontic therapy, if a small amount of coronal tooth structure has been lost then a direct composite restoration may be the restoration of choice (Cohen, S. and Hargreaves, 2006). Bonded direct composite restoration is a conservative option and is possible to achieve. The physical properties of composite include high compressive strengths of around 280 MPa and a Young modulus close to that of dentine in the region of 10 to 16 GPa (Sakaguchi and Powers, 2012). The high-quality surface finish and sealing ability achieved with bonding make it a popular choice. When cured well, composites are highly aesthetic. Shrinkage of composites after polymerisation tends to be a problem and affects the long-term success of the restoration. Incremental filling technique helps to reduce the stresses of shrinkage during polymerisation.

Traditionally, direct composite restorations have been placed in anterior teeth, which have had little previous restorations, or have not lost tooth

structure greater than the access cavity. Immediate sealing of the tooth can be achieved in these cases with a direct composite restoration. This will protect the root canal system from coronal leakage and recontamination with bacteria. Various studies in vitro have shown that small bonded restorations have similar fracture resistance to unrestored teeth (Reeh, Messer and Douglas, 1989). It should be emphasised the merit in retaining as much tooth structure as possible.

Composite restorations on posterior teeth generally tend to work better when the amount of tooth structure lost is limited. For example posterior teeth with an endodontic access cavity preparation with no other structural loss may be successful with conservative bonded restorations (Reeh, Messer and Douglas, 1989; Steele and Johnson, 1999).

When coronal tooth tissue is lacking, for example in one study it showed that endodontically treated teeth with a MOD cavity, the resistance to fracture is reduced by 69%. A direct composite in this situation may not be appropriate to place.

On the negative side, composites during polymerisation shrink. Material shrinkage causes gap formation especially in areas where the bond is the weakest. Adhesion of composite to the pulpal floor is less predictable than adhesion to coronal dentine (Kijsamanmith *et al.*, 2002).

2.8.2 Amalgam Restorations

Amalgam restorations have traditionally been used for the direct technique to restore teeth. Amalgam is a good, economical material, which can ensure a stable coronal seal, wear resistance, compression strength, good

polishing ability and excellent cost-benefit ratio (Polesel, 2014). However in root filled teeth the placement of a conventional amalgam restorations, which include interproximal extension but without cuspal coverage is largely contraindicated as the risk for cuspal or root fracture is high (Hansen and Asmussen, 1990). Amalgam restorations placed as an onlay with intraradicular retentions was shown to be an effective procedure and more tooth conserved in comparison to a full crown (Reeh, Messer and Douglas, 1989).

Problems with amalgam include its change in size as it expands by thermal expansion, this can lead to micro-cracks (Polesel, 2014). Other problems include the 'non-adhesive nature of the material, amalgam can corrode and discolouration of the gingivae or dentine can occur, creating unacceptable aesthetics (Cohen, S. and Hargreaves, 2006).

Amalgam restorations are used as core material, to build up a posterior tooth prior to crowning the tooth. The research on amalgam's performance as a core material is limited (Forde, 2011).

Hansen et al in 1990 looked at fracture resistance of amalgam restorations in root filled premolars. The teeth restored had lost either one or both marginal ridges. They showed that a third of teeth fractured within 3 years and around two thirds were lost after 10 years. The conclusion drawn was that amalgam wasn't a suitable material to restore root filled teeth that have lost marginal ridges (Hansen and Asmussen, 1990).

2.8.3 Glass Ionomer and Modified Glass Ionomer.

These are adhesive materials that are used for small restorations and build-ups. They can be used to eliminate undercuts in prepared teeth. They have a cariostatic effect by releasing fluoride and hence their rationale for their use.

However due to their low strength they are brittle and are not suitable in the replacement of unsupported cusps and in teeth with extensive loss of tooth structure (Hasan and Kuldeep, 2015). In posterior teeth glass ionomers can be indicated for the placement of a bulk core material (Wiegand, Buchalla and Attin, 2007).

Resin modified glass ionomers combine glass Ionomer and composite resin properties. The compressive strength is greater than that of glass ionomers but less than composites. They have uses as a core build-up material for moderate size cavities. They are disadvantaged by hygroscopic expansion, which can cause fracture of the ceramic crown. The glass Ionomer bond to dentine is that similar to that of composite to dentine. Resin composites have now are the material of choice for core fabrication (Cohen, S. and Hargreaves, 2006).

2.8.4 Indirect Restorations

Endodontically treated teeth can be restored with porcelain fused to metal crowns, full metal crowns, endocrowns, which is an adhesive monolithic ceramic restoration anchored in the pulp chamber, exploiting the micromechanical retention properties of the pulp-chamber wall (Bindl and

Mörmann, 1999), ceramic, metal and resin composite onlays. Onlays conserve tooth structure, whereas restoration with a full crown would involve reducing all cusps and axial walls. Onlays and overlays are made from resin composites or ceramics generally within a laboratory (Fedorowicz *et al.*, 2015).

When one marginal ridge is lost and the two adjacent cusps have been compromised and the other marginal ridges are healthy, then an onlay is usually indicated (Polesel, 2014). In endodontically treated teeth this option is not that common as root-filled teeth are usually heavily compromised.

When both marginal ridges have been lost the risks of tooth fracture are much higher (Hansen and Asmussen, 1990). The placement of a direct restoration may not be possible and therefore cuspal coverage with an overlay can reduce risk of fracture. The amount of tooth reduction when using an adhesive overlay can be about 50% less than that for full crown preparations (Edelhoff and Sorensen, 2002).

Chrepa et al showed high tooth survival rates of root-filled teeth restored with onlays. Making onlays a viable option for restoring root filled teeth (Chrepa *et al.*, 2014).

2.8.5 Gold restorations

Gold alloy as a material has excellent properties compared with amalgam. Gold restorations require more conservative tooth preparations, they have more durability and exhibit reduced biomechanical stress. However due to the poor aesthetics they are being used less and less. Gold alloy still continues to be the material of choice for longevity of restorations.

In posterior teeth where aesthetics is less of a concern gold onlays and crowns are still advocated. Especially in upper maxillary second molars or where interocclusal space is limited. These restorations will preserve more healthy tooth structure when compared with metal ceramic crowns (Forde, 2011).

2.8.6 Full crowns

Full crowns are becoming less and less indicated. This is as a result of newer adhesive techniques that have been developed that favour partial restorations as opposed to full coverage. However, when a lot of tooth structure has been lost, by restorative procedures or caries then a full coverage crown may be indicated.

The range of available materials has expanded and allows dentists to choose from a wide variety of materials suitable for crown restorations. Monolithic zirconia crowns and lithium disilicate crowns have been shown to offer optimal aesthetic and functional qualities over the short and medium term. Traditional metal ceramic have been mostly used for the restoration of posterior teeth and as bridge abutments and still remain the first choice restoration especially where there are less aesthetic demands (Cohen, S. and Hargreaves, 2006). If tooth structure is very limited then the cementation of a post is needed to provide retention for the core material to support the crown (Polesel, 2014).

There are many ways to restore the endodontically treated tooth. The choice of restoration is crucial to preserve the remaining tooth structure and can also influence the long-term prognosis of the tooth.

In the era of adhesive dentistry and focus on preserving tooth structure the days of the full coverage crowns may be limited.

The research available is unclear and confusing, and there is uncertainty about which restorations perform better comparatively when restoring the root filled tooth.

There are conflicting findings from systematic reviews in this field especially for evidence for the relative effectiveness of conventional restorations over indirect restorations for the restoration of root-filled teeth (Stavropoulou and Koidis, 2007; Fedorowicz *et al.*, 2015).

The aim of this research is to assess the effectiveness of direct restorations and indirect restorations for the restoration of the root filled posterior tooth. As mentioned before posts tend to weaken teeth, they can be challenging to place and in posterior teeth posts can be avoided. Previous systematic reviews having included teeth with posts in the inclusion criteria, this systematic review will focus on posterior root filled teeth without posts to assess the effectiveness of direct and indirect restorations. This aims to better inform clinicians and help their decision-making and choices when restoring root filled posterior teeth.

2.9 Research aims and objectives

Aims

The aims of this thesis are:

- To investigate the effectiveness of direct and indirect restorations for the coronal restoration of root-filled posterior teeth (molars and premolars) teeth without posts.
- To explore opinions of General Dental Practitioners (GDPs) in the U.K and the factors that influence decision-making when restoring root- filled posterior teeth

Objectives

- To systematically review the literature to assess the evidence for the effectiveness of direct and indirect restorations for coronal restoration of root-filled posterior teeth without posts.
- Explore the attitudes and confidence of GDPs in the private sector compared with NHS to restoring a posterior root filled tooth with direct or indirect restoration.
- Identify the factors which GDPs may take into consideration when deciding which type of restoration to place and determine which factors are more important to GDPs
- Assess the time interval for the GDP to place a final restoration on a root filled posterior tooth.

Chapter 3. Systematic review

3.1 Background

Root filled teeth are generally compromised teeth that have been structurally weakened due to various factors such as dental caries, pre-existing restorations or trauma (Sedgley and Messer, 1992).

The root canal system can become infected as a result of coronal leakage. Once the root canal becomes irreversibly inflamed or infected the tooth one of two options is required to treat the infection. This is either root canal treatment or extraction of the tooth. Root canal treatment aims to retain the tooth in the patient's mouth as well as eliminating infection (Saunders and Saunders, 1994).

The alternative to a root filling and a restoration is the extraction of the tooth. The latter option results in the total loss of the tooth, whereas the former option allows the tooth to be retained and serves as a more cost effective option when compared with an implant following tooth extraction (Pennington *et al.*, 2009).

These teeth are at a greater risk of fracture and, if they are not restored immediately, this can cause fracture of the tooth, which as a consequence may no longer be restorable. Root filled teeth can be restored with direct or indirect restorations otherwise known as intracoronal (such as amalgam, composite or glass Ionomer) or extracoronal restorations (such as crowns, onlays, endocrowns) respectively (Manocci *et al.*, 2005; Ferrari *et al.*, 2012).

Root filled posterior teeth are recommended to be restored after the root canal treatment is completed, ideally with coronal coverage, this helps to reduce the risk of fracture of the tooth (Chan *et al.*, 1999; Kumagai *et al.*, 1999). In coronal coverage, the cusps of the tooth are protected by a restoration in order to reduce the flexure of the cusps and protect against the forces of occlusion and subsequent fracture.

Sorensen and Martinoff 1984 (Sorensen and Martinoff, 1984) showed that coronal coverage of posterior root filled teeth (molars and premolars) improved the rate of clinical success or longevity of the restoration. An 8-year study by Salherabi et al (Salehrabi and Rotstein, 2004) of over a million root filled teeth showed that 97% of root filled teeth survived. The 3% that failed were either extracted, had re-root canal treatment or apical surgeries. Of these 3%, 85% had no coronal coverage. This study demonstrates the importance of coronal coverage for root filled teeth for long-term survival.

Direct restorations such as amalgam or composite are relatively inexpensive and simple to place. The dentist can usually place these restorations in a single visit. In contrast, indirect restorations such as crowns and onlays can be more challenging to place and require more than one patient visit, thus incurring increased costs. Indirect restorations are usually made from metal, porcelain or composite (Cohen, S. AND Hargreaves, 2006).

Posts such as pre-fabricated or cast may also be used to provide better retention for direct and indirect restorations (Bolla *et al.*, 2016). A post is

usually placed to provide retention for the core in a tooth with extensive loss of coronal structure (Schwartz and Robbins, 2004). Post placement does not strengthen or reinforce the tooth; the strength of the tooth and its resistance to fracture are derived from the residual tooth structure and surrounding alveolar bone (Assif and Gorfil, 1994). The placement of a post may increase the incidence of root fracture, especially in the case of an oversized root canal (Heydecke and Peters, 2002; Schwartz and Robbins, 2004).

Previous studies have looked at restoring root filled posterior teeth with direct and indirect restorations. A review in 2004 (Schwartz and Robbins, 2004), showed that root filled treated posterior teeth can be successfully restored with adhesive composite resin restoration when the tooth has minimum to moderate tooth loss. A 2015 systematic review published in the Cochrane Database of Systematic Reviews (Fedorowicz *et al.*, 2015), looked at single crowns versus conventional fillings for the restoration of root filled teeth. This review included one randomised control trial. The trial included looked at patients with premolars with no more than three surfaces lost and all teeth contained posts. The authors concluded that there was insufficient evidence to assess the effects of crowns compared to conventional fillings for the restoration of root filled teeth (Fedorowicz *et al.*, 2015).

In contrast, the authors of another systematic review of single crowns on root filled teeth concluded that root filled teeth, restored with a crown, showed an acceptable long-term survival of 10 years, while direct

restorations survived satisfactorily but only for a short period which was less than that of crowns (Stavropoulou and Koidis, 2007). However, these studies included teeth with posts and teeth with bridge and denture abutments as part of their inclusion criteria.

Deciding on which type of restoration is appropriate for the restoration of a root filled posterior tooth is based on very limited clinical evidence. Many factors, such as type of tooth, position of the tooth in the arch, the type of the opposing and patient factors such as parafunction habits, are involved in the treatment planning of the restoration of the root filled tooth. These must be considered with the risk factors when treatment planning.

The limitations of the previous reviews (Stavropoulou and Koidis, 2007., Fedorowicz *et al.*, 2015), were that they either looked at randomised controlled trials and included teeth with posts, and therefore limited their search. There is currently no systematic review that has been carried out to assess the effectiveness of direct and indirect coronal restorations for the restoration of the posterior root filled tooth without post.

Randomised controlled trials are very limited in this field, therefore attempts will be made to include high quality retrospective or prospective cohort studies to increase the number of studies to provide more information in this systematic review.

This review is important as the choice of restoration material can influence the long-term effectiveness of the root filled tooth. Posts tend to weaken teeth by removal of tooth structure and are expensive and difficult to place. Also, in the U.K., dentists who work in the NHS are not remunerated for

the placement of a post in a tooth. The current evidence to recommend a direct over an indirect coronal restoration for the restoration of root filled posterior teeth without post is limited. Previous reviews (Fedorowicz *et al.*, 2015), have included teeth with posts. This review will look at posterior root filled teeth that haven't been restored with posts. The findings of this review may help to inform U.K. dentists as they make clinical decisions when selecting the treatment of choice to restore root filled posterior teeth.

The research question for this review is, **'What is the effectiveness of direct and indirect coronal restorations, without posts, for the restoration of root filled posterior teeth?'**

3.2 Methods

Question: What is the effectiveness of direct and indirect coronal restorations for the restoration of root filled posterior teeth without posts?

A systematic review was conducted in accordance with internationally accepted methodology and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) statement (Moher *et al.*, 2009). This approach was undertaken to minimise potential bias in the review process by promoting transparency, quality methodology and better reporting.

3.2.1 Information sources and electronic searches

A detailed and systematic computerised search of electronic databases was conducted using the databases listed below, from their inception to

2019. The research team considered that, even although a lot of new materials and technologies are used in dentistry, many of the original older techniques are still being used in clinical practice by many clinicians today. Therefore, it was decided that the literature would be searched from as far back as possible. An information specialist who specialises in Health Sciences database searching provided advice on how to maximise the reach of the searches and how to best use specific search terms.

The reference lists of the retrieved and selected articles were hand searched for relevant possible studies.

Searches from inception to June 2019:

- Central
- MEDLINE
- EMBASE
- Web of science

The following search terms used were:

Direct restorations, indirect restorations, dental amalgam, glass ionomer cements, composite resin, crowns, inlays, onlays, overlays, endocrown, endodontics, endodontic treatment, root canal therapy, non-vital tooth, devital or pulpless teeth, resin cements, glass Ionomer cements, molars, premolars, bicuspids, posterior.

The searches had no language restrictions and were limited to human studies.

The results of the searches are presented in Appendix 1.

3.2.2 Eligibility criteria

The format of PICOS (Population, Intervention, Comparator, Outcomes, Study Design) was used to describe the inclusion criteria.

Population

Adults patients over the age of 18, of any gender, who had a root filled permanent posterior tooth (premolar or molar teeth), which required a restoration.

Intervention

These included direct restorations e.g. amalgam, composites and glass ionomers and indirect restorations, such as (single coverage crowns e.g. metal, metal-ceramic, all ceramic crowns or other indirect partial restorations, e.g. inlays, onlays, overlays, and 'endocrowns'), all used without posts.

Comparator

The comparators of interest were either direct or indirect restorations in studies with no posts or without comparators.

Outcome measures

Primary outcomes:

- Catastrophic failure of the restored tooth or restoration leading to direct extraction. Reasons for failure- endodontic complications, restoration failure.
- Non-catastrophic failure of the restoration requiring further treatment, this is categorised as failure of the restoration, i.e.

missing, broken, or required additional attention or replacement.

- Survival rate against fracture of tooth or restoration.
- The number and/or percentage of restorations that failed clinically or radiographically.
- Evaluation of the functional restorations in terms of marginal adaptation, restoration integrity, colour match, marginal discolouration, surface roughness and the presence of caries using the modified United States Public Health Service (USPHS) (Bayne and Schmalz, 2005), criteria (Appendix 2)

Secondary outcomes:

- Patient satisfaction and quality of life using any valid tool.
- Recurrent caries assessed clinically or by radiographs.
- Periodontal health status.
- Technical outcomes. For example, marginal fit of restoration and the cost of delivering the different interventions.

Study designs:

The following types of studies were included:

- Randomised and non-randomised controlled clinical trials, cohort studies (prospective and retrospective).
- Any study that included data from patients that had restorations without posts were included, even if the other subgroups included posts.

Exclusion criteria

The following types of studies were excluded:

- Studies that included the use of different types of bridge retainers, posts and partial dentures.
- Periodontally compromised teeth were excluded.
- Studies of patients aged less than 18 years, animal studies, and letters to editor, reviews, and case reports of less than 10 patients, non-English papers.
- Studies that focused on the restoration of anterior teeth.
- Studies that did not report any of the outcomes of interest.
- Studies that did not specify the type of restoration used.

3.2.3 Study selection

Stage 1. Two reviewers (AH and AAH) screened the titles and the abstracts identified via the electronic search results to determine their eligibility for inclusion in the review.

The full text papers of the potentially eligible studies were obtained. Where there were insufficient data in the title and abstract of the paper to make a clear inclusion /exclusion decision, the full texts of these papers were also obtained.

Stage 2. Once all of the full paper texts were obtained, the reviewers applied the inclusion and exclusion criteria. Studies that did not meet the inclusion criteria were excluded from the review. Details of the excluded studies are presented in Table 1.

3.2.4 Data extraction

From the studies that met the inclusion criteria, the following details were extracted and tabulated:

- Study characteristics, including study design, setting and geographical location of the study, length of follow-up, study funding, remaining tooth structure, time from endodontic treatment to restoration, restoration type, intervention and comparator (Table 2).
- Patient characteristics, including tooth type, pulp status, number of patients, number of restorations, age, ratio of male to female, study loss to follow-up. (Table 3).
- Study inclusion and exclusion criteria (Table 4).
- Outcomes, including outcomes defined in the studies, measurement of outcomes and any statistical analysis. (Table 5).

Data from the included studies were extracted by AH and checked by AB and JG.

3.2.5 Assessment of risk of bias in included studies/ quality assessment.

Two reviewers (AH and JG) independently assessed all of the studies for risk of bias using Down's and Black (Downs and Black, 1998) quality assessment tool. This tool can be used to evaluate both randomised and non-randomised controlled trials. The checklist is composed of 27

questions, with a possible total score of 28 for randomised studies and 25 for non-randomised studies. Ranges were given corresponding quality levels: excellent (26–28); good (20–25); fair (15–19); and poor (≤14), using the grading system suggested by Kennelly (J., 2011).

Data synthesis

Due to the heterogeneity of interventions, outcomes and study designs, meta-analysis could not be performed. The data are presented narratively.

3.2.6 Results

The process of study selection is shown in Figure 1. From the studies published from inception to 2019, initially 14,753 articles were identified from six databases. After removing the duplicates, 10166 articles remained. After examination of titles and abstracts, 10,045 records were excluded leaving potentially 121 articles reporting on the restoration of the root filled tooth. These articles were screened by their titles and abstracts in accordance with the inclusion criteria. Of these 121 articles, 109 articles were excluded and reasons for exclusion are listed in Table 1.

Twelve articles were included from the electronic searches, 6 comparative and 6 non-comparative studies. After thorough hand searching of key references, no more additional studies were retrieved.

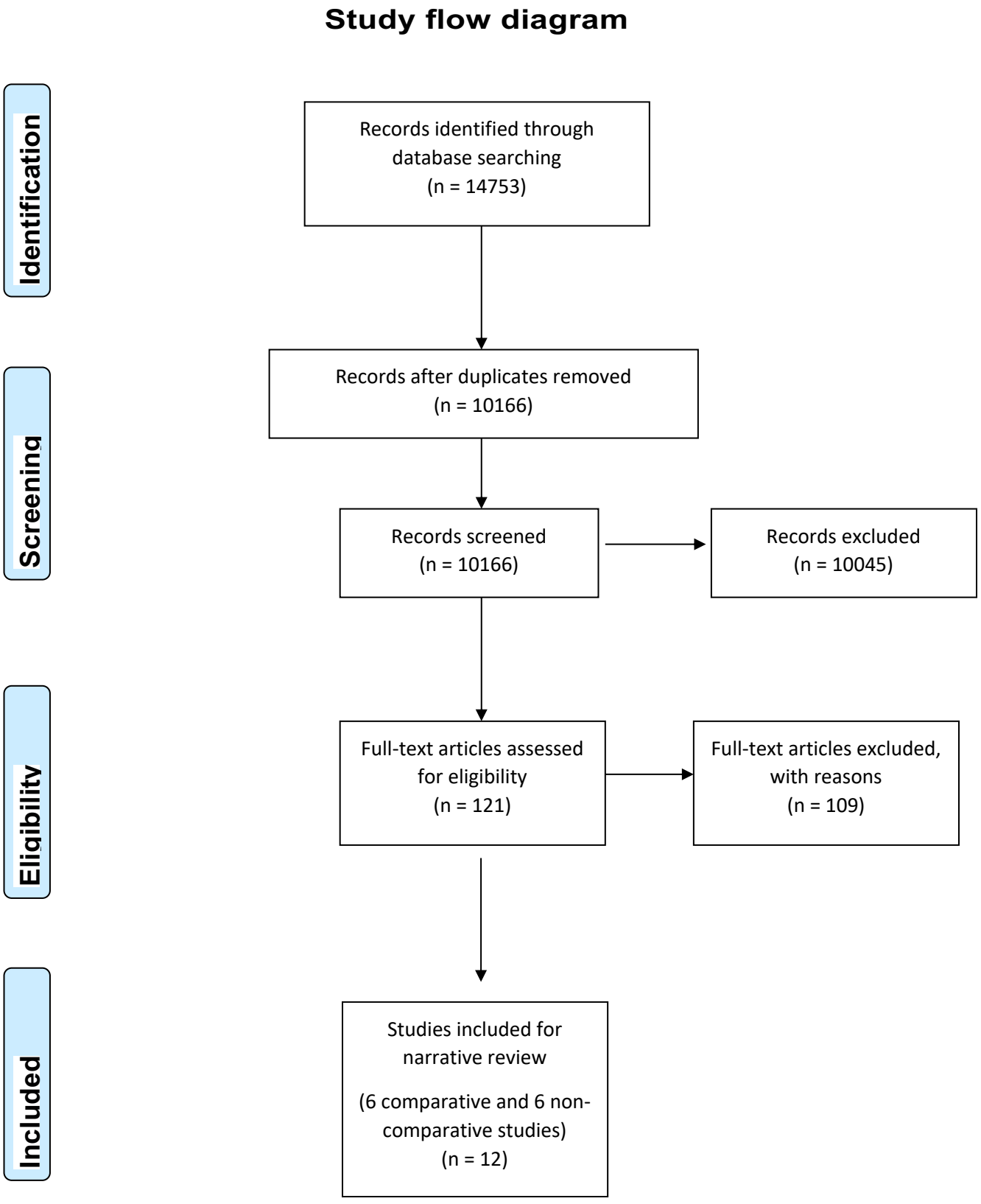


Figure 3.1. PRISMA (Preferred reporting items for systematic reviews and meta-analyses) Flowchart

3.3 Results of the quality assessment

Table 6 shows the results of the quality assessment of the included studies. The scoring relates to quality levels.

Reporting (maximum score of 10)

Comparative studies

- One comparative study by Nagasiri et al (Nagasiri and Chitmongkolsuk, 2005) scored very highly for reporting with a score of 9-10.
- Comparative studies by Scotti et al and Mannoci et al (Manocci *et al.*, 2005; Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015), compared a direct restoration with a restoration with a post, both scored 7 out of 10.
- Comparative studies both by Ferrari et al (Ferrari *et al.*, 2007, 2012), which looked at an indirect restoration compared with a restoration with a post scored 7 and 8 out of 10.

Non-comparative studies

- Non-comparative direct restoration studies by Hansen et al, Deliperi et al and Shafiei et al (Hansen and Asmussen, 1990; Deliperi, 2009; Shafiei, Memarpour and Doozandeh, 2010), score ranged from 7-8 out of 10.
- Non-comparative studies by Dias et al, Bindl et al and Chrepa et al (Bindl and Mörmann, 1999; Chrepa *et al.*, 2014; Dias *et al.*, 2018), looked at indirect restorations and scored between 5-8 out of 10.

External validity and bias (maximum score of 3)

Comparative studies

- The comparative studies all scored maximum points 3 out of 3.

Non-comparative studies

- Studies by Hansen et al, Deliperi et al and Shafiei et al (Hansen and Asmussen, 1990; Deliperi, 2008; Shafiei, Memarpour and Doozandeh, 2010), scored between 1-3 out of 3.
- Three studies scored maximum points Two studies, Chrepa et al and Real Dias et al (Deliperi, 2009; Chrepa *et al.*, 2014; Dias *et al.*, 2018), scored 2 out of 3 with one study losing a point for question 13 (Chrepa *et al.*, 2014), (were staff participating representative of patient's environment).

Internal validity-bias (maximum score of 7)

Comparative studies

- Studies by Ferrari et al, Mannoci et al and Nagasiri et al (Manocci *et al.*, 2005; Nagasiri and Chitmongkolsuk, 2005; Ferrari *et al.*, 2007), scored 4 out of 7.
- One study by Scotti et al (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015) from the comparative group seemed to attempt to blind assessors.
- All studies scored zero for attempt to blind participants.

Non-comparative studies

- None of the studies scored maximum points with the range being from 3-4 out of 7.
- Accurate outcome measures seem to be scored well for most of the non-comparative studies.

Internal validity confounding (maximum score of 6)

Comparative studies

- Scores ranged from 2-5 out of 6.
- One study by Scotti et al (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015), scored 2 out of 6, lost points due to lack of randomisation, adequate allocation concealment and reporting loss to follow up.
- Three studies by Dammaschke et al, Nagasiri et al and Ferrari et al (Nagasiri and Chitmongkolsuk, 2005; Ferrari *et al.*, 2007; Dammaschke *et al.*, 2013), scored 3 out of 6.
- Two studies by Ferrari et al and Mannoci et al (Manocci *et al.*, 2005; Ferrari *et al.*, 2012), scored 5 out of 6.

Non-comparative studies

- Real Dias et al score was 5 out of 6 (Dias *et al.*, 2018).
- Studies lost points due to, lack of randomisation, adequate allocation concealment and adequate adjustments for confounders.

(See tables 7&8 for breakdown of QA results)

3.4 Overall results

3.5 Comparative studies

There were six comparative studies included in the review.

3.5.1 Indirect restoration compared with direct restoration (comparative study, no posts)

Study characteristics (Table 2)

Dammaschke et al Study (Dammaschke *et al.*, 2013), was a retrospective study conducted in Germany in a university setting and also funded by the university. The follow up time was 9.7 years. The restorations compared in this study were Glass Ionomer (direct restoration), Amalgam (direct restoration), Composite (direct restoration) and Gold partial crowns (indirect restoration).

Patient characteristics (Table 3)

The study (Dammaschke *et al.*, 2013) looked at premolars and molars with a large number of restorations (n=676) The patient mean age was 56.2 years with the percentage of males being 51.9%. Loss to follow up was not reported in this study. The remaining tooth structure was between 1-4 walls.

Results (excluding posts and bridges abutments) (Table 5)

The outcome measure was tooth survival, which was defined as fracture of the tooth and /or restoration. Tooth survival ranged from 63% for glass Ionomer, 70.4% for amalgam, and 91.9% for composite to 100% for partial gold crown.

3.5.2 Direct restorations

Study characteristics (Table 2)

The study by Nagasiri et al (Nagasiri and Chitmongkolsuk, 2005) was a retrospective cohort study with a follow up period of 6 months to 10.2 years and was conducted in Thailand in a university setting. Funding of the study was not reported. The restorations that were compared were amalgam, composite and Intermediate Restorative Material (IRM).

Patient characteristics (Table 3)

Nagasiri et al (Nagasiri and Chitmongkolsuk, 2005) compared direct restorations in molar teeth only. The number of restored teeth was 220. The mean age of the participants was not reported but the range was from 15.7- 74.7 years old. Of these, 27% were males. Loss to follow up information was not reported. The amount of remaining tooth structure of the molars was between 0-4 walls.

Results (Table 5)

The outcome measure was tooth survival, and this was described as requiring a restoration, tooth repair, or extraction, had recurrent caries, crack/fracture, loss of restoration, fracture of tooth or restoration or a vertical root fracture. Estimated survival probability was also calculated (see Table 3). Composite restorations had a five-year survival probability of 0.38, amalgam was 0.17, and IRM was 0.2.

3.5.3 Direct restoration without post compared with direct restoration with post (comparative study)

Study characteristics (Table 2)

The study by Manocci et al was a randomised clinical trial (Manocci *et al.*, 2005). The other study was a retrospective clinical study by Scotti et al (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015). Both of the studies were carried out in Italy, one in private practice with no mention of funding (Manocci *et al.*, 2005) and one carried out in a teaching hospital and university funded (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015). The follow up period was between 3 and 5 years respectively.

Scotti et al (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015), compared a direct composite restoration with a composite restoration that was retained by a post. Manocci et al (Manocci *et al.*, 2005) compared amalgam with a composite restoration that was retained by a post.

Patient characteristics (Table 3)

Both studies compared a direct restoration with a post that was retained by an indirect restoration (Manocci *et al.*, 2005; Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015). Manocci et al (Manocci *et al.*, 2005) only looked at premolars whereas a Scotti et al (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015) looked at both molars and premolars. Manocci et al (Manocci *et al.*, 2005), study had 219 restorations and Scotti et al (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and

Berutti, 2015), had 376 with a mean age of 45 and 48.7 years respectively. The percentage of males was similar in both studies ranging at 47 and 49%. Loss to follow up information was reported in Manocci et al study only (Manocci *et al.*, 2005). Remaining tooth structure was three walls for the Scotti et al (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015) study but there was no mention of the amount of tooth remaining in the Manocci et al 2005 (Manocci *et al.*, 2005) study.

Results (excluding posts) (Table 5)

Outcome measures for the two studies were different. Manocci et al (Manocci *et al.*, 2005) looked at root fracture and restoration failure which was measured by post fracture, post decementation, clinical and/or radiographic evidence of a marginal gap between tooth and restoration and secondary caries. The results showed that the failure of amalgam restoration ranged from 0.93% at year 1 to 9% at year 5 in Manocci et al study (Manocci *et al.*, 2005). The outcome in Scotti et al study (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015) was restoration still being in function, which was measured using the USPHS criteria (Bayne and Schmalz, 2005) (Appendix 2). Restoration functionality was 78.12% over a period of 34.44 months in the group with composite restoration only (Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015). For the group with amalgam only, the restoration failure ranged from 0.93% at 1 year to 9% in 5 years (Manocci *et al.*, 2005).

3.5.4 Indirect restoration without post compared with restoration with post:

Study characteristics (Table 2)

The Ferrari et al 2012 study (Ferrari *et al.*, 2012) was a randomised controlled trial and the Ferrari et al 2007 study (Ferrari *et al.*, 2007) was a prospective comparison study, both studies were conducted in a private practice in Italy. The follow up period for the randomised controlled study was 6 years compared to 2 years for the other study. Funding was reported for one study (Ferrari *et al.*, 2007) only. The restorations that were compared with metal ceramic crowns were post-retained metal ceramic crowns for both groups.

Patient characteristics (Table 3)

Both studies (Ferrari *et al.*, 2007, 2012) both looked at premolars. The number of restorations were 240 in Ferrari et al 2007(Ferrari *et al.*, 2007), and 360 in Ferrari et al 2012 (Ferrari *et al.*, 2012), with the mean age of participants being reported in one study (Ferrari *et al.*, 2007), and not reported in the other study. The percentage of males (44%) was reported in one study (Ferrari *et al.*, 2007) and was not reported by the other study. Loss to follow up information was reported on in the 2012 study (Ferrari *et al.*, 2012) but not in the study by 2007 study (Ferrari *et al.*, 2007). The amount of remaining tooth structure was the same for both studies and ranged from 0-4 walls.

Results (excluding posts) (Table 5)

For one study (Ferrari *et al.*, 2007), the primary outcome was tooth survival; over a 2 year period, survival was 81.3% for metal ceramic crown only. In the study by Ferrari et al 2012 (Ferrari *et al.*, 2012), the main outcome measures were tooth survival and restoration success; 85.9% tooth survival for the metal ceramic crown after 6 years and 42.1% restoration success.

3.6 Non-comparative studies

There were six non-comparative studies included in the review, of these, three studies, Hansen et al, Deliperi et al and Shafiei et al (Hansen and Asmussen, 1990; Deliperi, 2009; Shafiei, Memarpour and Doozandeh, 2010) looked at direct restorations and three studies, Bindl et al, Chrepa et al and Real-Dias et al (Bindl and Mörmann, 1999; Chrepa *et al.*, 2014; Dias *et al.*, 2018) looked at indirect restorations.

3.6.1 Direct restorations

Study characteristics (Table 2)

Two studies were prospective (Deliperi, 2009; Shafiei, Memarpour and Doozandeh, 2010) and one was retrospective (Hansen and Asmussen, 1990). Two studies were conducted in a practice setting (Hansen and Asmussen, 1990; Deliperi, 2009) and one study did not report this information (Deliperi, 2009). The follow up period ranged from 1 year to 20 years. Funding was obtained by two studies and one study did not report this information (Shafiei, Memarpour and Doozandeh, 2010). Two studies (Hansen and Asmussen, 1990; Deliperi, 2009) conducted their studies in

Europe and the other was conducted in Asia (Shafiei, Memarpour and Doozandeh, 2010). The time from endodontic treatment to restoration was reported by two studies (Deliperi, 2009; Shafiei, Memarpour and Doozandeh, 2010), and not by the other (Hansen and Asmussen, 1990). All three studies looked at different restorations; these were amalgam (Hansen and Asmussen, 1990), composite (Deliperi, 2009), and combined composite and amalgam restoration (Shafiei, Memarpour and Doozandeh, 2010).

Patient characteristics (Table 3)

One study looked at premolars and molar teeth (Hansen and Asmussen, 1990), and the other two studies looked at molars only (Deliperi, 2009) and premolars only (Shafiei, Memarpour and Doozandeh, 2010). The number of restorations included in the studies were 35, 36 and 1639 for all three studies respectively (Hansen and Asmussen, 1990; Deliperi, 2009; Shafiei, Memarpour and Doozandeh, 2010). The number of males and patient age were only reported by one study (Shafiei, Memarpour and Doozandeh, 2010). Loss to follow-up was reported in two studies (Deliperi, 2009; Shafiei, Memarpour and Doozandeh, 2010) only. The range of remaining tooth structure was between 2- 3 walls for Hansen et al study (Hansen and Asmussen, 1990), 2-4 walls for Deliperi et al study (Deliperi, 2009) and 2 walls (buccal and palatal walls) for Shafiei et al study (Shafiei, Memarpour and Doozandeh, 2010).

Results (Table 5)

In one study (Hansen and Asmussen, 1990) the main outcome was restoration survival. The authors found that, over a 20-year period, the survival of premolar root filled treated teeth that were restored with amalgam restorations was shortest if they were upper premolars with mesio-occlusal-distal (MOD) cavities (27% cumulative survival). Premolars with mesio-distal/distal-occlusal (MO/DO) cavities restored with amalgam (except upper second premolars) had the best survival over 20 years (74% cumulative survival) (Hansen and Asmussen, 1990). The other two studies (Hansen and Asmussen, 1990; Shafiei, Memarpour and Doozandeh, 2010) showed 100% tooth and restoration survival for one and three years respectively and the outcome was measured by the USPHS (Appendix 2).

3.6.2 Indirect restorations

Study characteristics (Table 2)

Bindl et al and Chrepa et al were retrospective studies (Bindl and Mörmann, 1999; Chrepa *et al.*, 2014) and one study by Real-Dias et al was prospective (Dias *et al.*, 2018). Only one study reported on the setting, which was a clinic in general practice (Chrepa *et al.*, 2014). The countries where the studies took place were reported in two studies (Bindl and Mörmann, 1999; Dias *et al.*, 2018), Switzerland and Portugal respectively. There was no mention of the country where the study took place in the study by Chrepa et al (Chrepa *et al.*, 2014). Follow up period ranged from 24 months to 5 years. Funding for the research was not reported in any of the studies. The restorations that were assessed in the studies were

indirect composite cuspal coverage restorations (Chrepa *et al.*, 2014; Dias *et al.*, 2018) and endocrowns (Bindl and Mörmann, 1999).

Patient characteristics (Table 3)

All three studies looked at both molar and premolar teeth (Bindl and Mörmann, 1999; Chrepa *et al.*, 2014; Dias *et al.*, 2018). The number of restorations included was 19, 150 and 189 respectively (Bindl and Mörmann, 1999; Chrepa *et al.*, 2014; Dias *et al.*, 2018) . Mean age was only reported in one study (Chrepa *et al.*, 2014), the other two studies had no mention of the participants ages. The percentage of male participants was reported by all three studies and ranged from 27-54% of males. Loss to follow up information was reported in all three studies. Remaining tooth structure was from 3-4 walls for one study (Dias *et al.*, 2018) and not reported on by the two other studies.

Results (Table 5)

The outcome measure was tooth survival in one study (Bindl and Mörmann, 1999) and tooth and restoration survival in the other two studies (Chrepa *et al.*, 2014; Dias *et al.*, 2018). All three studies used the USPHS for measuring the outcome (refer to Appendix 2). Tooth survival ranged from 95-100% and restoration survival ranged from 95-96%. None of the three studies included descriptions of any statistical analysis.

3.7 Discussion

This is the first systematic review, to the author's knowledge, that has investigated the effectiveness of coronal direct and indirect restorations for the restoration (without posts) of the root filled posterior tooth. The aim of the review was to assess the literature and find relevant evidence to inform and guide practitioners as they make decisions about the best choice of a coronal restoration for a root filled posterior tooth without a post.

There was only one included study (Dammaschke *et al.*, 2013), which was retrospective and non-randomised that compared direct restorations with indirect restorations. This study compared three types of direct restorations (glass Ionomer, amalgam and composite (n=235) and one type of indirect restoration, partial gold crowns (n=24). Results showed that the survival of teeth treated with gold partial crowns was greater than the survival of teeth treated with composite, amalgam and glass ionomer. The results of this study suggest that restoring root filled posterior teeth with gold partial crowns is more effective than using direct restorations. However, due to the very low numbers of restorations in the gold partial crown group, we consider that it is not appropriate to make any definite claims as to the relative effectiveness of partial gold crowns compared with other types of direct restorations. Should this study be repeated, a larger patient population would need to be recruited with more equal numbers of direct and indirect restorations to ensure a more robust comparison.

No other studies were identified that could directly answer the research question. All of the other studies were either

1. Non-comparative and looked at the effectiveness of one single type of restoration.

2. Comparative studies that compared direct restorations with other direct restorations

3. If the studies compared one type of restoration with another, there was one group that contained restorations with posts. The results of these studies do not provide sufficient evidence for a robust comparison of the relative effectiveness of direct versus indirect restorations without posts.

As noted in the introduction, Cochrane database of systematic reviews, carried out a similar systematic review (Fedorowicz *et al.*, 2015). This review identified one randomised controlled trial (Mannocci *et al.*, 2002). Which recruited 117 participants with root filled premolar teeth restored with carbon fibre posts that were randomised into two groups one with a full coverage metal ceramic crown and one with a direct adhesive composite restoration. After a 3-year recall period neither of the groups experienced a failure that could not be repaired. The authors concluded that there was no difference between the two treatment methods for the risk of failure of the restoration. This study was not eligible for inclusion in this systematic review as both groups of teeth were restored with posts.

3.7.1 Strengths and limitations of included studies

All but one study included in this review were of fair to poor quality, with the exception of one study which was regarded as good quality (Nagasiri and Chitmongkolsuk, 2005). The majority of the studies had poor internal validity. Only three studies (Manocci *et al.*, 2005; Ferrari *et al.*, 2012; Dias

et al., 2018) randomised patients to treatment groups, two of these studies were randomised controlled trials (Manocci *et al.*, 2005; Ferrari *et al.*, 2012). However, what was not clear was how the randomisation process was performed. No power calculations were evident and therefore it was difficult to assess if the samples were large enough to capture statistical significant difference in the outcomes between the trial arms.

None of the studies were able to blind participants or assessors. When patients are receiving dental restorations, consent must be obtained for a specific type of restoration, so it is almost impossible to carryout participant blinding. Not being able to blind patients may affect patient's behaviour in the study and influence their responses to subjective outcome measures. The randomised controlled trial by Ferrari et al (Ferrari *et al.*, 2012) had independent investigators and assessors. The clinician was not involved in assessing the outcomes, thereby reducing bias. Also, two well trained assessors in evaluating clinical and radiographic signs were used, and any disagreements could be resolved through discussion. In the study by Ferrari et al (Ferrari *et al.*, 2007), there was no mention of the assessors and whether any attempt to blind them was made.

There was a large range of follow up periods for the 12 studies, from 1 year up to 20 years. For longevity of dental restorations, it is important to conduct long-term studies to be able to assess the performance of the restoration over long periods of time. The majority of the studies had a follow up period of less than 5 years.

The amount of tooth structure remaining is a vital confounding factor and plays an important role when choosing a restoration for a root filled tooth. With the exception of three studies (Bindl and Mörmann, 1999; Manocci *et al.*, 2005., Chrepa *et al.*, 2014), this information was well documented across the remaining included studies.

Four of the included studies looked at premolar teeth (Manocci *et al.*, 2005; Ferrari *et al.*, 2007, 2012; Shafiei, Memarpour and Doozandeh, 2010), two studies looked at molar teeth (Nagasiri and Chitmongkolsuk, 2005., Deliperi, 2009). One study (Hansen and Asmussen, 1990) looked at molar and premolar teeth. Molars and premolars are different in size and as a result can withstand difference forces. It is difficult to determine if restorations perform just as well when only one type of tooth is investigated.

Of the twelve included studies, there were similar numbers of prospective and retrospective studies and two randomised controlled trial. Advantages of retrospective studies are that a longer follow up period can be examined. However, the reliability of the information is often dependent on who entered the data at the time of the study. In addition, where data are ambiguous, the interpretation of the data by the original investigator may be prone to bias – this is difficult to ascertain without access to the original study investigators.

The twelve included studies had different outcome measures ranging from tooth survival, restoration survival or success, technical outcome of the restoration. This made comparison of the results of the studies

inappropriate. Also, the populations of the studies varied from patients treated in a university hospital by dentists or undergraduate students to patients treated in private practice. Therefore, due to heterogeneity in many areas of the studies, no definitive conclusions could be made.

3.7.2 Strengths and limitations of the review process

The search strategy for this review was comprehensive and similar to previous reviews carried out. Non-English papers were excluded from this review. Using non-English papers is challenging. These papers are selected based on their English abstracts. The full paper then needs to be translated into English. It is possible that there could be interpretation problems when translating non-English texts. It was for this reason non-English papers were excluded.

The author found it challenging to find papers that compared direct with indirect restorations for root filled posterior teeth without posts. It was decided that, if a restoration without a post was compared with a restoration, be it direct or indirect but with a post, then that paper would be included, and only data relating to the 'no post group' would be included.

One reviewer examined all the references and abstracts for eligibility, and this was not carried out by a second person. This may be considered as a potential flaw in the review process, having a second reviewer to check references is useful when there is uncertainty as to which papers to include in the review.

As part of the review process was using the Down's and Black checklist (Downs and Black, 1998) was used to quality assesses the studies. This tool is used to assess the methodological quality of not only randomised controlled trials but also non-randomised control trials. The performance of this tool has previously been shown to be good for randomised controlled trials and also for non-randomised trials. This tool was preferred over the Newcastle Ottawa tool, which is for non-randomised studies only. The Down's and Black tool were piloted before use. This allowed the author to become familiar with the tool before interpreting the results. Two reviewers checked the data extractions (AH and AB) and two reviewers conducted the quality assessment (AH and JG). This is standard methodology used in systematic reviews with the purpose of ensuring quality of the review.

3.7.3 Overall implications of the review

Overall, it can be said that root filled teeth that have been restored have a good long-term prognosis. Amalgam restorations have been shown to survive less well than composite restorations according to Nagisiri et al (Nagasiri and Chitmongkolsuk, 2005), and Dammaschke et al (Dammaschke *et al.*, 2013). The possible explanation for this relates to the adhesive properties of composite restorations, which mean less of the tooth need to be removed. Achieving a good seal prevents bacteria contamination, whereas amalgam restorations require undercuts, slots and grooves, which may weaken the tooth structure further. Amalgam use as a restorative material is declining clinically owing to its' mercury content (Alexander *et al.*, 2017), and the cosmetic demands of patients. The majority of the teeth treated in this review were mainly premolars.

Premolars are anatomically smaller teeth than molars and if restored previously, have less tooth structure available than molars and tend to be more difficult to restore. Consequently, this leads to a higher rate of tooth fracture (Ng, Mann and Gulabivala, 2011). It is therefore difficult to conclude which restoration works better in which tooth, a premolar or molar. More trials on molars need to be carried out in order to make any relevant conclusions.

Indirect composite restorations demonstrated promising results with two studies (Chrepa *et al.*, 2014; Dias *et al.*, 2018), included in this review showed high survival rates. However, due to the differences in study designs, methodologies and outcome measures, within these studies and the other included studies no clear conclusion can be made for the effectiveness of this material over other materials for restoration of the root filled posterior teeth. What can be said is, that this type of restoration should be considered when restoring root filled teeth with minimal to moderate tooth loss as composite will have more tooth available for adhesive bonding. More research into the use of this type of material is recommended.

Most of the studies were carried out in a mixture of private practice and university/hospital settings. The operators ranged from highly skilled and experienced to undergraduates' students and in many different countries. It is, therefore, difficult to generalise any of the findings.

The lack of blinding of investigators and outcome assessors created challenges in the study designs of the included studies. This increases the

potential for bias. In some trials where the assessor and the operator were the same person this gives rise to a biased assessment. Overall the included studies were at high risk of bias. In the randomised controlled studies (Manocci *et al.*, 2005; Ferrari *et al.*, 2012), included due to the inability to blind assessors and investigators and also lack of information about allocation concealment and no power calculation, it is difficult to judge whether the study's results are reliable. Experienced clinicians who perform such treatments day in day out will automatically have a better outcome due to their greater experience and familiarity with the materials that they use. It would not be expected that a young newly qualified dentist with limited clinician experience could achieve the same results and perform the treatment to the same high standard.

Outcomes measures using the USPHS (Bayne and Schmalz, 2005), are subjective and using this tool to measure restoration longevity can introduce bias as it may not be accurately and consistently applied across different studies.

This review was limited to the qualitative description of studies. The heterogeneity of the methods and techniques and the risk of bias make meta-analysis impossible.

This systematic review looked at the effectiveness of the coronal restoration on the root filled posterior tooth without post. However, previous studies show that quality of the root canal treatment when combined with a coronal restoration affects the overall success of the root filled tooth (Ray and Trope, 1995). Information about the quality of the root canal treatment,

and patient reported outcomes would be very beneficial to be able to see not only how clinicians define success but also if the patients are symptom free and if the root filled restored tooth has had a positive or negative impact on their lives. It could be probable that the patient may favour a direct restoration over an indirect restoration due to the ease of placement, low cost to the patient and reduced visits to the dentist. There was a lack of data on this in the included studies of this review, this would be important to research in the future.

The review question, 'what is the effectiveness of direct and indirect coronal restorations on root filled posterior teeth without posts', was very focused and looked to not include root filled posterior teeth restored with posts. This made the inclusion of papers very specific.

3.8 Conclusion

The methodologies used in the studies were poor and there was a lot of missing information. There is insufficient evidence to recommend a direct or indirect coronal restoration in a root filled posterior tooth without post.

There is limited evidence to suggest that direct restorations are more effective than indirect restorations (or vice versa) in root filled posterior teeth without posts.

3.8.1 Recommendations

To improve the evidence more research into this important area is justified. Paying attention to the amount of tooth structure remaining when restoring root filled teeth is key to good decision-making. Although this is very difficult to standardise in a clinical trial, information about the width and height of

the remaining tooth structure would be very useful to know. Studies should include patients with similar caries and periodontal risks and be performed in different settings to see if one setting is more advantageous than the other. Future studies should aim to reduce bias with attempts, where possible, to blind the assessors.

Long-term prospective studies with larger sample sizes looking at equal numbers of premolar and molars teeth should be considered. Valid and reliable outcomes measures should be given greater consideration. USPHS (Bayne and Schmalz, 2005) (Refer to Appendix 2) methods to evaluate the restoration performance should be considered due to their reproducibility, however, as it is not an objective measure, it is not without flaw. Future studies should also include information examining patient's expectations, Patient Reported Outcomes (PROMs), the cost effectiveness of the different types of restorations, and the implications it has for the patient and clinician alike.

(Refer to table 9 for summary of discussion)

Table 1. A list of all the studies that were rejected at the second stage with the reasons for rejection from the systematic review.

Study	**Reason for rejection**
Abu-Hassan, M. I., et al. (2000). "Stress distribution associated with loaded ceramic onlay restorations with different designs of marginal preparation. An FEA study." Journal of Oral Rehabilitation 27(4): 294-298.	Vitro study
Adolphi, G., et al. (2007). Direct resin composite restorations in vital versus root-filled posterior teeth: a controlled comparative long-term follow-up." Operative Dentistry 32(5): 437-442	Vital teeth
Agnol, R., et al. (2013). "Influence of resin cements on cuspal deflection and fracture load of endodontically-treated teeth restored with composite inlays." Acta Odontologica Scandinavica 71(3-4): 664-670.	Vitro study
Ahrari, F., et al. (2010). Clinical evaluation of bonded amalgam restorations in endodontically treated premolar teeth: a one-year evaluation." Journal of Contemporary Dental Practice [Electronic Resource] 11(5): 009-016	Posts included
Akbar, I. (2015).Knowledge, attitudes and practice of restoring endodontically treated teeth by dentists in north of saudi arabia." International Journal of Health Sciences 9(1): 41-49	Non clinical study
Akbari, M., et al. (2016).One-year clinical comparison of survival of endodontically treated premolar restored with different direct restoration technique: A prospective cohort study." Razavi International Journal of Medicine 4 (4)	Posts included
Alfouzan, K., et al. (2016). Radiographic Diagnosis of Periapical Status and Quality of Root Canal Fillings in a Saudi Arabian Subpopulation." Oral Health & Preventive Dentistry 14(3): 241-248.	Anterior teeth included
Alley, B. S., et al. (2004).A comparison of survival of teeth following endodontic treatment performed by general dentists or by specialists." Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics 98(1): 115-118.	No mention of type of restoration used

Alshiddi, I. F. and A. Aljinbaz (2016).Fracture resistance of endodontically treated teeth restored with indirect composite inlay and onlay restorations - An in vitro study." The Saudi Dental Journal 28(1): 49-55	Vitro study
Ananviriyaporn, S., et al. (2012). "Fracture resistance of endodontically treated teeth restored with fiber-reinforced composite posts and composite core with varying remaining coronal tooth structure." Journal of the Medical Association of Thailand 95 Suppl 1: S115-119.	Vitro study
Aquilino SA, Caplan DJ. Relationship between crown placement and the survival of endodontically treated teeth. Journal of Prosthetic Dentistry 2002;87:256–63.	Anterior teeth present
Arunpraditkul, S., et al. (2009).Fracture resistance of endodontically treated teeth: three walls versus four walls of remaining coronal tooth structure." Journal of Prosthodontics 18(1): 49-53.	Vitro study
Baba, N. Z., et al. (2009).Restoration of endodontically treated teeth: the seven keys to success." General Dentistry 57(6): 596-603	Posts included
Beier, U. S., et al. (2012). Clinical performance of all-ceramic inlay and onlay restorations in posterior teeth." International Journal of Prosthodontics 25(4): 395-402	Vital teeth
Bernhart, J., et al. (2010). Cerec3D endocrowns--two-year clinical examination of CAD/CAM crowns for restoring endodontically treated molars." International Journal of Computerized Dentistry 13(2): 141-154	Posts included
Biacchi, G. R., et al. (2013). "The endocrown: an alternative approach for restoring extensively damaged molars." Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry .. [et al.]. 25(6): 383-390.	Case report
Burke, F. M., et al. (2009). Technical quality of root canal fillings performed in a dental school and the associated retention of root-filled teeth: a clinical follow-up study over a 5-year period." Journal of Oral Rehabilitation 36(7): 508-515.	Unable to split anterior and posterior teeth data
Cakici, E. B., et al. (2016). Assessment of periapical health, quality of root canal filling, and coronal restoration by using cone-beam computed tomography." Nigerian Journal of Clinical Practice 19(5): 673-677	Outcome Periapical status

Can Say, E., et al. (2006). Clinical evaluation of posterior composite restorations in endodontically treated teeth." Journal of Contemporary Dental Practice [Electronic Resource] 7(2): 17-25.	Journal unable to be located
Caplan DJ, Kolker J, Rivera EM, Walton RE. Relationship between number of proximal contacts and survival of root canal treated teeth.International Endodontic Journal2002;35:193–9	Anterior teeth included
Carvalho, A. O., et al. (2016). Influence of Adhesive Core Buildup Designs on the Resistance of Endodontically Treated Molars Restored With Lithium Disilicate CAD/CAM Crowns." Operative Dentistry 41(1): 76-82	Vitro study
Clinical value of cast post-core porcelain fused to metal crown in restorating residual root and crown of molars L.G. Chen, F.N. He and J.H. Huang Human Yi Ke da Xue Xue Bao, 28 (2003), pp. 385-387	Non- English paper
Cheung, G. S. and T. K. Chan (2003). Long-term survival of primary root canal treatment carried out in a dental teaching hospital." International Endodontic Journal 36(2): 117-128	No information of type of restoration used
Cheung, W. (2005). A review of the management of endodontically treated teeth. Post, core and the final restoration." Journal of the American Dental Association 136(5): 611-619	Posts included
Chugal, N. M., et al. (2007). Endodontic treatment outcome: effect of the permanent restoration." Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics 104(4): 576-582	No separation of anterior and posterior teeth
Costa, G. M., et al. (2017). Factors Affecting the Periapical Status of Root-Filled Canals: A Cross-Sectional Study at the Undergraduate Level." International Journal of Dentistry 2017: 7413204	Posts included
Craveiro, M. A., et al. (2015) Influence of coronal restoration and root canal filling quality on periapical status: clinical and radiographic evaluation." Journal of Endodontics 41(6): 836-840	Outcome is Periapical status
Creugers, N. H., et al. (2005). A 5-year prospective clinical study on core restorations without covering	Posts included

crowns." International Journal of Prosthodontics 18(1): 40-41.	
Creugers N.H., et al (2005) Five year follow-up of a prospective clinical study on various types of core restorations. International Journal of Prosthodontics 2005;18:34–9.	Posts included
Rosa Rodolpho, P. A., et al. (2006). A clinical evaluation of posterior composite restorations: 17-year findings." Journal of Dentistry 34(7): 427-435.	Vital teeth
Dammaschke, T., et al. (2003). Long-term survival of root-canal-treated teeth: a retrospective study over 10 years." Journal of Endodontics 29(10): 638-643	Posts included
Dawson, V. S., et al. (2016). Periapical Status of Root-filled Teeth Restored with Composite, Amalgam, or Full Crown Restorations: A Cross-sectional Study of a Swedish Adult Population." Journal of Endodontics 42(9): 1326-1333.	Outcome is Periapical status
De Moor, R. J., et al. (2000). Periapical health related to the quality of root canal treatment in a Belgian population."International Endodontic Journal 33(2): 113-120.	Outcome is Periapical status
Deliperi, S. (2008). Direct fiber-reinforced composite restoration in an endodontically-treated molar: A three-year case report." Operative Dentistry 33(2): 209-214	Case report
Dugas, N. N., et al. (2003). Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations." International Endodontic Journal 36(3): 181-192.	Outcome is Periapical status
Dukic, W., et al. (2010) Clinical evaluation of indirect composite restorations at baseline and 36 months after placement. Operative Dentistry 35, 156-164	Vital teeth
Dunne, S. (2014). Summary of: Influence of root canal fillings on longevity of direct and indirect restorations placed within the General Dental Services in England and Wales." British Dental Journal 216(6): 358-359	Posts included
Eliyas, S., et al. (2015). Restoration of the root canal treated tooth." British Dental Journal 218(2): 53-62.	Non clinical study
El-Damanhoury H. M et al (2015),, Fracture resistance and microleakage of endocrowns utilizing three CAD-CAM blocks Oper. Dent., 40 (2) pp. 201-210	Vitro study

Ellner S, Bergendal T, Bergman B. Four post-and-core combinations as abutments for fixed single crowns: a prospective up to 10-year study. International Journal of Prosthodontics 2003;16:254–9.	Post included
Fedorowicz,Z., et al. (2015). Single crowns versus conventional fillings for the restoration of root filled teeth." Cochrane Database of Systematic Reviews	Posts included
Ferrari, M., et al. (2017). Post-Retained Single Crowns versus Fixed Dental Prostheses: A 7-Year Prospective Clinical Study." Journal of Dental Research 96(13): 1490-1497	Posts included
Fonzar, F., et al. (2009). The prognosis of root canal therapy:a 10-year retrospective cohort study on 411 patients with 1175 endodontically treated teeth." European Journal of Oral Implantology 2(3): 201-208.	Outcome Periapical status
Fransson, H., et al. (2016). Survival of Root-filled Teeth in the Swedish Adult Population." Journal of Endodontics 42(2): 216-220	No information of type of restoration used
Freilich, M. A., et al. (1992) Direct and indirect evaluation of posterior composite restorations at three years. Dental Materials 8, 60-64	Vital teeth
Frisk, F. and M. Hakeberg (2005). A 24-year follow-up of root filled teeth and periapical health amongst middle aged and elderly women in Goteborg, Sweden." International Endodontic Journal 38(4): 246-254.	Outcome is Periapical status
Frisk, F., et al. (2015). Is apical periodontitis in root filled teeth associated with the type of restoration?" Acta Odontologica Scandinavica 73(3): 169-175.	Anterior teeth included
Geerts, G., et al. (2011). Fracture resistance of endodontically treated premolars with fibre-reinforced composite restorations." European Journal of Prosthodontics & Restorative Dentistry 19(1): 25-31	Vitro study
Geiger, S., et al. (2008). Fracture resistance of endodontically treated teeth restored with combined composite-amalgam restorations." Quintessence International 39(2): e58-62.	Vitro study

Georgopoulou, M. K., et al. (2008). Periapical status and quality of root canal fillings and coronal restorations in a Greek population." Quintessence International 39(2): e85-92.	Outcome is Periapical status
Gillen, B. M., et al. (2011). Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis." Journal of Endodontics 37(7): 895-902	Outcome is Periapical status
Glazer B. (2000);Restoration of endodontically treated teeth with carbon fibre posts—a prospective study. Journal of the Canadian Dental Association 66:613–8.	Posts included
Gohring, T. N. and O. A. Peters (2003) Restoration of endodontically treated teeth without posts." American Journal of Dentistry 16(5): 313-317.	Denture abutments used
Grandini S., et al (2005), Clinical evaluation of the use of fiber posts and direct resin restorations for endodontically treated teeth. International Journal of Prosthodontics;18:399–404.	Posts included
Gunduz, K., et al. (2011). Cross-sectional evaluation of the periapical status as related to quality of root canal fillings and coronal restorations in a rural adult male population of Turkey." BMC Oral Health 11: 20.	Outcome is Periapical status
Gurgan, S., et al. (2017) Four-year randomized clinical trial to evaluate the clinical performance of a glass ionomer restorative system. Operative Dentistry 40, 134-143	Vital teeth
Hayashi, M., et al. (2006). Fracture resistance of pulpless teeth restored with post-cores and crowns." Dental Materials 22(5): 477-485.	Vitro study
Hayashi, M., et al. (2004). Quantitative Measurement of Marginal Disintegration of Ceramic Inlays." Operative Dentistry 29(1): 3-8.	Vital teeth
Hayashi, M., et al. (2000). Eight-year clinical evaluation of fired ceramic inlays." Operative Dentistry 25(6): 473-481.	Vital teeth
Hayashi, M., et al. (1998). 6-year clinical evaluation of fired ceramic inlays." Operative Dentistry 23(6): 318-326	Vital teeth
Hayashi, M. and N. H. Wilson (2003). Marginal deterioration as a predictor of failure of a posterior	Vital teeth

composite." European Journal of Oral Sciences 111(2): 155-162.46	
Hayashi, M., et al. (2003) Quality of marginal adaptation evaluation of posterior composites in clinical trials. Journal of Dental Research 82, 59-63	Vital teeth
Heffernan, M., et al. (2003). Prognosis of endodontically treated teeth?" Quintessence International 34(7): 558-561.	Case report
Hiremath, H., et al. (2017). Evaluation of different fibers and biodentine as alternates to crown coverage for endodontically treated molars: An in vitro study." Journal of Conservative Dentistry 20(2): 72-75.	Vitro study
Hommez, G. M., et al. (2002). "Periapical health related to the quality of coronal restorations and root fillings." International Endodontic Journal 35(8): 680-689.	Outcome is Periapical status
Homsy, F., et al. (2015). Considerations for Altering Preparation Designs of Porcelain Inlay/Onlay Restorations for Nonvital Teeth." Journal of Prosthodontics 24(6): 457-462	Vital teeth included
Imura, N., et al. (2007). The outcome of endodontic treatment: a retrospective study of 2000 cases performed by a specialist." Journal of Endodontics 33(11): 1278-1282.	Unable to separate post and no post teeth
Isufi, A., et al. (2016). Fracture resistance of endodontically treated teeth restored with a bulkfill flowable material and a resin composite." Annali di Stomatologia 7(1-2): 4-10.	Vitro study
Johnson, J. K., et al. (1976). Evaluation and restoration of endodontically treated posterior teeth." Journal of the American Dental Association 93(3): 597-605.	Case report
Jongsma, L. A., et al. (2012) Clinical success and survival of indirect resin composite crowns: results of a 3-year prospective study." Dental Materials 28(9): 952-960	Vital teeth
Karaman, E., et al. (2017). Three-year clinical evaluation of class II posterior composite restorations placed with different techniques and flowable composite linings in endodontically treated teeth." Clinical Oral Investigations 21(2): 709-716.	No separation of posterior teeth
Kayahan, M. B., et al. (2008). Periapical health related to the type of coronal restorations and quality of root	No mention of type of

canal fillings in a Turkish subpopulation." Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics 105(1): e58-62.	teeth anterior or posterior
Kolker, J. L., et al. (2005). Teeth with large amalgam restorations and crowns: factors affecting the receipt of subsequent treatment after 10 years." Journal of the American Dental Association 136(6): 738-748;	Vital teeth
Kolpin, M., et al. (2014). Composite filling or single crown? The clinical dilemma of how to restore endodontically treated teeth." Quintessence International 45(6): 457-466.	Case report
Laske, M., et al. (2016). Longevity of direct restorations in Dutch dental practices. Descriptive study out of a practice based research network." Journal of Dentistry 46: 12-17	Vital teeth
Lempel, E., et al. (2015). Retrospective evaluation of posterior direct composite restorations: 10-year findings." Dental Materials 31(2): 115-122.	Vital teeth
Linde LA. (1984). The use of composites as core material in root filled teeth. II. Clinical investigation. Swedish Dental Journal 8:209–16.	Bridges included
Lucarotti, P. S., et al. (2014). Influence of root canal fillings on longevity of direct and indirect restorations placed within the General Dental Services in England and Wales." British Dental Journal 216(6): E14	Anterior teeth included
Lumley, P. J., et al. (2008) Ten-year outcome of root fillings in the General Dental Services in England and Wales." International Endodontic Journal 41(7): 577-585	No mention of type of restoration
Lynch, C. D., et al. (2004). The influence of coronal restoration type on the survival of endodontically treated teeth." European Journal of Prosthodontics & Restorative Dentistry 12(4): 171-176	Anterior teeth included
Manhart, J., et al. (2000) Three-year clinical evaluation of direct and indirect composite restorations in posterior teeth. Journal of Prosthetic Dentistry 84, 289-296	Vital teeth
Mannocci, F., et al. (2002). Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct	Posts included

composite restoration." Journal of Prosthetic Dentistry 88(3): 297-301	
Mannocci, F., et al. (2009). Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration." International Endodontic Journal 42(5): 401-405.	Posts included
Meyenberg, K. (2013) The ideal restoration of endodontically treated teeth - structural and esthetic considerations: a review of the literature and clinical guidelines for the restorative clinician." The European Journal Of Esthetic Dentistry : Official Journal Of The European Academy of Esthetic Dentistry 8(2): 238-268	Non clinical study
Pallesen, U. and J. W. Dijken (2015) A randomized controlled 30 years follow up of three conventional resin composites in Class II restorations. Dental Materials 31, 1232-1244	Vital teeth
Pallesen, U. and V. Qvist (2003) Composite resin fillings and inlays. An 11-year evaluation. Clinical Oral Investigations 7, 71-79	Vital teeth
Pratt, I., et al. (2016). Eight-Year Retrospective Study of the Critical Time Lapse between Root Canal Completion and Crown Placement: Its Influence on the Survival of Endodontically Treated Teeth." Journal of Endodontics 42(11): 1598-1603	Type of restoration not mentioned
Perdigão, J., et al. (2012). Randomized clinical trial of two resin-modified glass ionomer materials: 1-year results. Operative Dentistry 37, 591-601	Vital teeth
Ray, H. A. and M. Trope (1995). Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration." International Endodontic Journal 28(1): 12-18.	No mention on type of restoration or if post is present or not
Ricucci, D., et al. (2011). A prospective cohort study of endodontic treatments of 1,369 root canals: results after 5 years." Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics 112(6): 825-842	Outcome is Periapical status
Rocca, G. T. and I. Krejci (2013). Crown and post-free adhesive restorations for endodontically treated posterior teeth: from direct composite to endocrowns." The	Case report

European Journal Of Esthetic Dentistry : Official Journal Of The European Academy of Esthetic Dentistry 8(2): 156-179.	
Salameh, Z., et al. (2010). Effect of different onlay systems on fracture resistance and failure pattern of endodontically treated mandibular molars restored with and without glass fiber posts." American Journal of Dentistry 23(2): 81-86.	Vitro study
Salameh, Z., et al. (2008). Fracture resistance and failure patterns of endodontically treated mandibular molars with and without glass fiber post in combination with a zirconia-ceramic crown." Journal of Dentistry 36(7): 513-519.	Vitro study
Salameh, Z., et al. (2007). Effect of different all-ceramic crown system on fracture resistance and failure pattern of endodontically treated maxillary premolars restored with and without glass fiber posts." Journal of Endodontics 33(7): 848-851.	Vitro study
Salehrabi, R. and I. Rotstein (2004). Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study." Journal of Endodontics 30(12): 846-850.	Type of restoration not mentioned
Sedrez-Porto, J. A., et al. (2016). Endocrown restorations: A systematic review and meta-analysis." Journal of Dentistry 52: 8-14.	Vitro study
Segura-Egea, J. J., et al. (2004). Periapical status and quality of root fillings and coronal restorations in an adult Spanish population." International Endodontic Journal 37(8): 525-530.	Outcome Periapical status
Sequeira-Byron, P., et al. (2015). Single crowns versus conventional fillings for the restoration of root-filled teeth." Cochrane Database of Systematic Reviews	Posts used
Setzer, F. C., et al. (2011). Long-term prognosis of endodontically treated teeth: a retrospective analysis of preoperative factors in molars." Journal of Endodontics 37(1): 21-25.	Outcome Periapical status
Siqueira, J. F., Jr., et al. (2005). Periradicular status related to the quality of coronal restorations and root canal fillings in a Brazilian population." Oral Surgery Oral	Outcome Periapical status

Medicine Oral Pathology Oral Radiology & Endodontics 100(3): 369-374.	
Skupien, J. A., et al. (2013). A practice-based study on the survival of restored endodontically treated teeth." Journal of Endodontics 39(11): 1335-1340	Anterior posterior teeth not separated
Skupien, J. A., et al. (2016). Survival of Restored Endodontically Treated Teeth in Relation to Periodontal Status." Brazilian Dental Journal 27(1): 37-40.	Outcome periodontal status
Stavropoulou, A. F. and P. T. Koidis (2007). A systematic review of single crowns on endodontically treated teeth." Journal of Dentistry 35(10): 761-767.	Posts included
Suksaphar, W., et al. (2017). Survival rates against fracture of endodontically treated posterior teeth restored with full-coverage crowns or resin composite restorations: a systematic review." Restorative Dentistry & Endodontics 42(3): 157-167.	Posts included
Tronstad, L., et al. (2000). Influence of coronal restorations on the periapical health of endodontically treated teeth." Endodontics & Dental Traumatology 16(5): 218-221	Outcome is Periapical status
Trope, M. and L. Tronstad (1991). Resistance to fracture of endodontically treated premolars restored with glass ionomer cement or acid etch composite resin." Journal of Endodontics 17(6): 257-259	Vitro Study
Valderhaug, J., et al. (1997). Assessment of the periapical and clinical status of crowned teeth over 25 years." Journal of Dentistry 25(2): 97-105.	Outcome is Periapical status and teeth with posts used
Wallerstedt D,. et al (1984). A follow-up study of Screwpost retained amalgam crowns. Swedish Dental Journal;(8):165–70.	Posts included
Wegner P.K., et al (2006) Survival rate of endodontically treated teeth with posts after prosthetic restoration. Journal of Endodontics ;32:928–31	Posts included

Table 2. Study characteristics of all the 12 included studies.

Study characteristics							
Study	**Study design**	**Setting**	**Country**	**Follow up period**	**Funding**	**Restoration type (number of restoration)**	**Intervention** **(I)** **Comparator** **(C)**
Comparative study (n=6)							
(Dammaschke *et al.*, 2013)	Retrospective study	University dentists and undergraduates School of Dental Science, Westphalian Wilhelms-University	Germany	9.7 years	Wilhelms-University	Glass Ionomer (n=110)(direct) vs Amalgam (n=98) (direct) vs Composite (n=37) (direct) vs Gold partial crowns (n=24) (indirect) vs Posts (n=61)	Glass Ionomer (C) Amalgam (C) Composite (C) Gold partial crown (C) Posts (C)

						(indirect)	
(Nagasiri and Chitmongkolsuk, 2005)	Retrospective cohort study	University	Thailand	Ranged from 6 months to 10.2 years	Not reported	Amalgam (n=14) vs Composite (n=195) vs IRM (n=11) (all direct restorations)	Not statedNot
(Manocci *et al.*, 2005)	RCT	Private practice	Italy	5 years	Not reported	Amalgam (n=107) (direct) vs Composite with post (n=109) (indirect)	Amalgam (C) Composite with post (I)
(Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015)	Retrospective clinical study	University undergraduate students	Italy	3 years	University of Turin	Composite (n=128) (direct) vs Composite with post (n=119) (indirect)	Composite (I) Composite no posts (C)
(Ferrari *et al.*, 2007)	Prospective clinical study	Private practice	Italy	2 years	University of Siena Dentsply, Italy	Metal ceramic crown (n=120) (indirect) vs	Metal ceramic crown (C) Metal ceramic crown with post

						Metal ceramic crown with post (n=120) (indirect)	(I)
(Ferrari *et al.*, 2012)	RCT Groups defined based on amount of dentine left at the coronal level after root canal treatment and before abutment preparation. Within each group, teeth were randomly subdivided into 3 groups based on the restorative procedure	Private practice	Italy	6 years	Not reported	Metal ceramic crown without post (n=115)(indirect) vs Metal ceramic crown with customised post (n=114) (indirect) vs Metal ceramic crown with prefabricated post (n=115) (indirect)	Metal ceramic crown without post (I) Metal ceramic crown with customised post (C) Metal ceramic crown with prefabricated post (C)
Non-comparative study (n=6)							
(Hansen and Asmussen, 1990)	Retrospective study	General practice Data were collected from 91 dentists between Jan and Oct 1988	Denmark	20 years	Research Foundation of the Danish Association and the Research Foundation of Dental Aktieselskabet af 1934	Amalgam (direct) (n=1639)	Amalgam (I)

(Deliperi, 2009)	Prospective cohort study	Not reported	Italy	1 year	Ribbond and Ultra-dent Inc provided all necessary materials	Composite (direct) (n=35)	Composite (I)
(Shafiei, Memarpour and Doozandeh, 2010)	Prospective cohort study	Private practice	Iran	3 years	Not reported	Composite Amalgam (direct) (n=36)	Composite Amalgam (I)
(Bindl and Mörmann, 1999)	Retrospective study	Clinic	Switzerland	26 months (mean)	Not reported	Endocrown (indirect) (n=19)	Endocrown (I)
(Chrepa *et al.*, 2014)	Retrospective study	Clinic (January 2008 to February 2010)	Not reported	24-52 months (median 37 months)	Not reported	Resin Composite onlay (indirect) (n=189)	Resin Composite onlay (I)
(Dias *et al.*, 2018)	Prospective clinical study	Not reported	Portugal	5 years	Not reported	Resin Composite cuspal coverage (indirect) (n=150)	Resin Composite cuspal coverage (I)

RCT-Randomised controlled trial

Table 3. Characteristics of participants from all the included studies

Patient characteristics							
Study	**Tooth type**	**Number of patients**	**Number of restorations**	**Mean age at time of treatment (years)**	**Males (%)**	**Loss to follow up**	**Remaining tooth structure (number of walls)**
Comparative studies (n=6)							
(Dammaschke *et al.*, 2013)	Molars and Premolars	676	676	56.2 (range= 18.1 to 76)	51.9%	Not reported	1-4
(Nagasiri and Chitmongkolsuk, 2005)	Molars	203	220	Mean not reported (range=15.7 to 74.7)	27%	Not reported	0-4
(Manocci *et al.*, 2005)	Premolars	219	219	45 (range=32 to 63)	47%	Reported 91.7% over 5 years Amalgam group 1	Not reported
(Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015)	Molars and Premolars	247	376	48.7	53%	Not reported	3

(Ferrari *et al.*, 2007)	Premolars	210	240	54 (range=18 to 76)	44.3%	None	0-4
(Ferrari *et al.*, 2012)	Premolars	345	360	Not reported	Not reported	Reported 11.9% at 6 years	0-4
Non-comparative studies (n=6)							
(Hansen and Asmussen, 1990)	Molars and Premolars	Not reported	1639	Not reported	Not reported	Not reported	2-3 walls
(Deliperi, 2009)	Molars	30	35	18 years or older	Not reported	None	2-4 walls
(Shafiei, Memarpour and Doozandeh, 2010)	Premolars	36	36	35 (28 to 52)	45%	3 patients were unavailable at 3 years	Buccal and palatal walls
(Bindl and Mörmann, 1999)	Molars and Premolars	13	19	Not reported	69%	Reported	Not reported
(Chrepa *et al.*, 2014)	Molars and Premolars	153	189	52 (range=27 to 78)	54%	None	Not reported
(Dias *et al.*, 2018)	Molars and Premolars	150 patients	150	Not reported	53%	None	3-4 walls MO/DO and MOD cavities

Table 4. Details of the Inclusion and Exclusion criteria of the included studies.

Study	Inclusion criteria	Exclusion criteria
Comparative studies (n=6)		
(Dammaschke *et al.*, 2013)	Teeth treated at School of Dental Science Treatments and examinations fully recorded Patients participated with recall system after enododontic treatment provided by School of Dental Science One restoration per patient Latest examination was after January 2006 (to ensure observation period of 5 years) Tooth had one approximal contact and opposing dentition with occlusal load	Teeth with insufficient root canal treatment or periodontal problems and teeth that have been surgically treated teeth
(Nagasiri and Chitmongkolsuk, 2005)	Teeth were included if they did not have provisional crowns, definitive restorations with cuspal coverage or with dowel and core and/or crown restorations	Third molars and teeth with less than half of occluso gingival tooth height remaining at the time of endodontic treatment
(Manocci *et al.*, 2005)	Only teeth without previous endodontic treatment presenting with a Class II carious lesion and intact cusp structure were included. The teeth were required to be in occlusal function following restoration and none were used as abutments for fixed or removable prostheses	Patients with shortened dental arches were excluded from the study. Patients wearing removal partial dentures, periodontal attachment loss more than 40% of root length, Gingival Index was greater than 1
(Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015)	At least one posterior tooth with a restoration following root canal treatment with a follow up period of 12 months	Significant loss of tooth structure which needed indirect restoration, teeth without at least one proximal contact, Full Mouth Plaque scores of >20%, absence of occlusal load, patients with history of bruxism
(Ferrari *et al.*, 2007)	Root filled premolars in occlusal function with natural tooth, and in interproximal contact with two adjacent teeth, no periapical lesion	Not reported

(Ferrari *et al.*, 2012)	The selected teeth needed to be in occlusal function with a natural tooth and in interproximal contact with two adjacent natural teeth. If the teeth had already been endodontically treated, the inclusion criteria of symptom-free root canal filling and a minimum apical seal of 4 mm, without any periapical lesion on the X-ray, had to be met by the tooth to be restored	Not reported
Non-comparative studies (n=6)		
(Hansen and Asmussen, 1990)	Root filled premolar or first of second molar with an MO, DO or MOD amalgam restoration	No cuspal coverage amalgam overlays, no class V restoration Unopposed teeth (without antagonist).
(Deliperi, 2009)	MO, DO, MOD Class II restorations Replacement of amalgam or composite resin restorations due to secondary decay, fracture of either the filling material or tooth structure Teeth with one or two missing cusps Teeth in occlusion and having proximal contact with adjacent teeth Molars	Patients with occlusal parafunction Teeth with severe internal discolouration Smokers Pregnant or nursing mothers Root filled teeth with root canal fillings terminating more than 2mm from the radiographic apex Teeth with residual cavity walls less than 1 mm or with complete loss of the clinical crown
(Shafiei, Memarpour and Doozandeh, 2010)	Root filled maxillary first and second premolars with buccal and palatal cusps. Teeth in occlusion and neighbouring teeth without abutment for fixed or removable prosthesis	Smokers, medical problems, severe bruxism, periodontal attachment loss, gingival index greater than 1 and those unable to attend regular appointments
(Bindl and Mörmann, 1999)	Patients with Cerec endo-crowns that had a service time of more than 14 months	Not reported
(Chrepa *et al.*, 2014)	Patients with one posterior tooth with composite placed after root canal treatment	Root filled teeth with significant coronal tooth structure loss restored with crown Pre-existing onlay or crown restorations Teeth with previous root canal treatment

		Patients with bruxism Less than 2 years of follow-up following restoration
(Dias *et al.*, 2018)	Premolars and molars with recently performed endodontic treatment requiring restorative procedures	Teeth with Class I cavities or previously restored with posts, definitive restorations with cuspal coverage, core reconstructions, or crowns

Table 5. The overall results obtained from the included studies

Study	Outcome	How is it measured	Relevant statistical analysis
Comparative studies (n=6)			
(Dammaschke *et al.*, 2013)	Tooth survival defined as: Fracture of tooth and/or restorations	**Tooth survival** Glass Ionomer- 63% (63/100) 9.4 years (mean) Amalgam – 70.4% (69/98) 10.4 years (mean) Composite- 91.9% (34/37) 9.6 years (mean) Partial gold crown- 100% (24/24) 8.9 years (mean)	Log rank test
(Nagasiri and Chitmongkolsuk, 2005)	Treatment outcome was defined as a failure if there were negative findings in the condition of a tooth that required a restoration, tooth repair, or extraction Failure characteristics of tooth changes included recurrent caries at the margin of a restoration, crack/fracture line, loss of restoration, fracture of tooth or restoration, and/or vertical root fracture. A change in colour was not considered failure	Estimated survival probability: Composite: 0.96 (1 year); 0.9 (2 year); 0.38 (5 year) Amalgam: 0.93 (1 year); 0.77 (2 years); 0.17 (5 years) IRM: 0.91 (1 year); 0.60 (2 years); 0.20 (5 years) Median survival time: Composite (4.2 years), Amalgam (3 years) and IRM (2.2 years)	P=0.0083 Type of material associated with survival. Log rank analysis

(Manocci *et al.*, 2005)	Failure of restoration= root fracture, post fracture, post decementation, clinical and/or radiographic evidence of a marginal gap between tooth and restoration, secondary caries	Amalgam restoration failure: 1 year- 1/107= 0.93% 3 year- 3/105= 2.86% 5 year- 9/100= 9%	Year 1, year 3 and year 5 overall failure rate: no statistically significant difference between amalgam and post restoration (p>0.50)
(Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015)	Restoration functionality- marginal adaptation, restoration integrity, colour match, marginal discolouration, surface roughness, presence of caries. Using USPHS	Restoration functionality at the 34.44 months median observation period = 78.12%	One sided t- test
(Ferrari *et al.*, 2007)	Tooth survival. Failure defined as: Post debonding, post fracture, vertical/horizontal root fracture, failure of core, requiring new coronal restoration, displacement of crown, need for re-endodontic treatment	Tooth survival at 2 years = 81.3% (45/240)	For no posts (HR= 4.9, 95% CI 2.4 to 10.3; p<0.001)
(Ferrari *et al.*, 2012)	Tooth survival= outcome in presence of relative and absolute failures. Restoration success= outcome in the absence of absolute and relative failures. Absolute failures= root fractures leading to tooth extraction.	Tooth survival – 85.9% for no post group after 6 years - Restoration success –42.1% for no post	Cox regression analysis

Non-comparative studies direct restorations			
(Hansen and Asmussen, 1990)	Restoration cumulative survival defined as: retention of both cusps	Cumulative restoration survival rate: (A) Teeth with MO/DO cavities except upper 2nd premolars: at 3 years 90%, at 10 years 84%, at 20 years 74% (B) Lower premolars with MOD cavity, upper and lower molars with MOD cavity, and upper second premolar with MO/DO cavity: at 3 years 83%, at 10 years 61%, at 20 years 38% (C) Upper premolars with MOD cavity: At 3 years 72%, at 10 years 43%, at 20 years 27%	Restoration survival: Difference between B and C is statistically significant ($p<0.005$) after 1 year; difference between A and B is statistically significant ($p<0.005$) after 2 years. The difference between with cumulative survival rate of group A and those of the other groups increased very rapidly: after5 years ($p<0.001$)
(Deliperi, 2009)	Tooth survival and restoration survival (not clearly defined)	No failure was reported, and alpha scores were recorded for all parameters	None
(Shafiei, Memarpour and Doozandeh, 2010)	Tooth survival and restoration survival (not clearly defined)	36/36 (100%) for tooth and restoration survival (excluding three non-attenders at year 3) Two restorations showed a slight discrepancy at the composite-amalgam interface after 1 year ($p>0.05$). Four restorations exhibited slight discoloration of the composite veneering after three years ($p<0.05$). No restoration exhibited fracture after 3 years	See previous column

Non comparative studies indirect restorations			
(Bindl and Mörmann, 1999)	Tooth survival defined as: Endocrowns remaining in function	18/19 (95%) tooth survival USPHS (baseline vs follow up) Marginal adaptation= 22% increase (72% to 94%) Adhesive interface= 33% Surface texture= 11% Shade= 6% Proximal contact= 28% Balance contact= 39%	None
(Chrepa *et al.*, 2014)	Tooth survival=clinically unacceptable defect of restoration that required its replacement Restoration survival=restoration remaining in situ	Tooth survival=100% Restoration survival=96.8% (183/189) USPHS Alpha rating for all evaluation criteria ranged from 83.1% to 100%	None
(Dias *et al.*, 2018)	Tooth survival=tooth still functional and still possible to be restored. Restoration success=tooth not needing a new restoration, tooth repair, or extraction during follow up period	Tooth survival 100% (150/150) Restoration success 96% (144/150) 2-5 years	None

HR=hazard ratio; USPHS=United States Public Health Service (refer to Appendix 2)

Table 6. Results of the quality assessment using the Downs and Black checklist for the 12 studies.

Downs and black checklist item	(Dammaschke *et al.*, 2013)	(Nagasiri and Chitmongkolsuk, 2005)	(Manocci *et al.*, 2005)	(Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015)	(Ferrari *et al.*, 2007)	(Ferrari *et al.*, 2012)	(Hansen and Asmussen, 1990)	(Deliperi, 2009)	Shafiei 2010)	(Bindl and Mörmann, 1999)	(Chrepa *et al.*, 2014)	(Dias *et al.*, 2018)
Type of restoration	Direct with indirect	Direct	Direct with post	Direct with a post	Indirect with post	Indirect with post	Direct	Direct	Direct	Indirect	Indirect	Indirect
Study Design	Comparative	Comparative	Comparative	Comparative	Comparative	Comparative	Non comparative	Non comparative	Non comparative	Non comparative	Non comparative	Non comparative
Reporting												
Q1:	1	1	1	1	1	1	1	1	1	1	1	1
Q2:	1	1	1	1	1	1	1	1	1	1	1	1
Q3:	1	1	1	0	1	0	0	1	1	0	1	0
Q4:	1	1	1	1	1	1	1	1	1	1	1	1
Q5:	1	1	1	0	1	1	1	1	0	0	0	1
Q6:	1	1	1	1	1	1	1	1	1	1	1	1
Q7:	UTD	1	1	1	1	1	1	0	0	0	0	0
Q8:	0	1	0	1	0	0	0	0	0	0	0	1

Q9:	1	0	0	1	1	1	1	1	1	1	1	1
Q10:	1	1	1	1	1	1	1	0	1	0	0	1
Total	*8*	*9*	*8*	*8*	*8*	*8*	*8*	*7*	*7*	*5*	*6*	*8*
External validity and bias												
Q11:	1	1	1	1	1	1	1	1	1	UTD	1	1
Q12:	1	1	1	1	1	1	1	1	1	UTD	1	UTD
Q13:	1	1	1	1	1	1	1	1	1	1	0	1
Total	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*1*	*2*	*2*
Internal validity and bias												
Q14:	0	0	0	0	0	UTD	0	0	0	0	0	0
Q15:	0	0	1	UTD	0	0	0	0	0	0	0	0
Q16:	0	0	0	0	0	0	0	0	0	0	0	0
Q17:	UTD	1	UTD	1	1	UTD	1	0	0	0	0	0
Q18:	1	1	1	1	1	1	1	0	1	0	0	1
Q19:	1	1	1	1	1	1	1	1	1	1	1	1
Q20:	1	1	1	1	1	1	1	1	1	1	1	1
Total	*3*	*4*	*3*	*4*	*4*	*3*	*4*	*2*	*3*	*2*	*2*	*3*
Internal validity-confounding (selection bias)												
Q21:	1	1	1	1	1	1	1	1	1	1	1	1
Q22:	0	1	0	1	UTD	1	0	1	1	1	0	1
Q23:	0	0	0	1	0	1	0	0	0	0	0	1

Q24:	0	0	0	1	0	0	0	0	0	0	0	0
Q25:	1	1	1	0	1	1	1	0	0	0	0	1
Q26:	1	UTD	0	1	1	1	0	1	1	1	1	1
Total	*3*	*3*	*2*	*5*	*3*	*5*	*2*	*3*	*3*	*3*	*2*	*5*
Q27:	UTD	0	UTD	0	0	UTD	0	UTD	0	0	0	0
Total	**18 (fair)**	**20 (good)**	**14 (poor)**	**19 (fair)**	**18 (fair)**	**18 (fair)**	**17 (fair)**	**14 (poor)**	**16 (fair)**	**11 (poor)**	**14 (poor)**	**17 (fair)**

Key to the QA questions

Q1: Aim clearly described

Q2: Outcomes clearly described

Q3: Patients characteristics clearly described

Q4: Interventions clearly described

Q5: Principal confounders clearly described

Q6: Main findings clearly described

Q7: Random variability for the main outcome provided

Q8: Adverse events reported

Q9: Lost to follow up reported

Q10: Actual p-value reported

Q11: Sample asked to participate representative of the population

Q12: Sample agreed to participate representative of the population

Q13: Staff participating representative of patient's environment

Q14: Attempt to blind participants

Q15: Attempt to blind assessors

Q16: Data dredging results stated clearly

Q17: Analysis adjusted for length of follow up

Q18: Appropriate statistics

Q19: Reliable compliance

Q20: Accurate outcome measures

Q21: Same population

Q22: Participants recruited at the same time

Q23: Randomised?

Q24: Adequate allocation concealment?

Q25: Adequate adjustment for confounders

Q26: Loss to follow up reported?

Q27: Did the study have sufficient power to detect a clinically important event?

Table 7.The breakdown of the quality assessment for each question asked for each study, expressed as a percentage.

Quality indicator: Does study provide clear description of . . .	**Percentage% (n) of studies meeting quality indicator**
Reporting quality sub-scale scores	
Q1: Aim clearly described	100% (12)
Q2: Outcomes clearly described	100% (12)
Q3: Patients characteristics clearly described	58% (7)
Q4: Interventions clearly described	100% (12)
Q5: Principal confounders clearly described	50% (6)
Q6: Main findings clearly described	100% (12)
Q7: Random variability for the main outcome provided	8% (1)
Q8: Adverse events reported	25% (3)
Q9: Lost to follow up reported	75% (9)
Q10: Actual p-value reported	75% (9)
External validity quality sub-scale scores	
Q11: Sample asked to participate representative of the population	66% (8)
Q12: Sample agreed to participate representative of the population	66% (8)
Q13: Staff participating representative of patient's environment	75% (9)
Internal validity-bias quality sub-scale scores	
Q14: Attempt to blind participants	0% (0)

Q15: Attempt to blind assessors	8% (1)
Q16: Data dredging results stated clearly	75% (9)
Q17: Analysis adjusted for length of follow up	33% (4)
Q18: Appropriate statistics	75% (9)
Q19: Reliable compliance	92% (11)
Q20: Accurate outcome measures	92% (12)
Internal validity-confounding quality sub-scale scores	
Q21: Same population	100% (12)
Q22: Participants recruited at the same time	58% (7)
0Q23: Randomised?	25% (3)
Q24: Adequate allocation concealment?	8% (1)
Q25: Adequate adjustment for confounders?	58% (7)
Q26: Loss of follow up reported?	75% (9)

Table 8. Overall quality score shown per subsection of the quality assessment tool

Study	(Dammaschke *et al.*, 2013)	(Nagasiri and Chitmongkolsuk, 2005)	(Manocci *et al.*, 2005)	(Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015)	(Ferrari *et al.*, 2007)	(Ferrari *et al.*, 2012)	(Hansen and Asmussen, 1990)	(Deliperi, 2009)	(Shafiei, Memarpour and Doozandeh, 2010)	(Bindl and Mörmann, 1999)	(Chrepa *et al.*, 2014)	(Dias *et al.*, 2018)
Reporting scores	8	9	7	7	8	7	5	6	7	5	6	8
External validity scores	3	3	1	1	3	3	3	2	3	1	2	0
Internal validity-bias scores	4	5	5	4	5	3	4	3	3	2	3	4
Internal validity-confounding scores (selection bias)	3	3	4	2	2	5	2	3	3	3	2	4
Power	0	0	0	0	0	0	0	0	0	0	0	0
Total	18	20	17	14	18	18	14	14	16	11	13	16

Table 9. A table summarising the discussion of each of the 12 included studies.

Summary of discussion		
Study: Indirect restorations compared with restorations with post	**Limitations and applicability to clinical practice**	**Commentary**
(Dammaschke *et al.*, 2013)	Good documentation of remaining tooth structure. Possible bias as study was retrospective.	Long observation period (9.7 years on average).
(Ferrari *et al.*, 2012)	RCT study. Good documentation of remaining tooth structure. Independent assessors and investigators. No power calculation performed.	Only RCT in this systematic review. Long observation period (6 years).
(Ferrari *et al.*, 2007)	Good documentation of remaining tooth structure. No mention of assessors.	Short follow up period (2 years).
Study: Direct restorations compared with direct restorations with post	**Limitations and applicability to clinical practice**	**Commentary**
(Scotti, Eruli, Comba, Paolino, Alovisi, Pasqualini and Berutti, 2015)	Operators were students.	Outcome measures were very subjective. Large sample.
(Manocci *et al.*, 2005)	Study could be generalised to practice as study conducted in a private clinic. Only conducted on premolars. Some mention of tooth structure.	Good follow up period (5 years).

	Randomisation clear but no power calculation	
Study: Comparative direct restorations	**Limitations and applicability to clinical practice**	**Commentary**
(Nagasiri and Chitmongkolsuk, 2005)	No information on premolars only molars. No blinding of participants, investigators or assessors.	Composite restorations survived best. Good follow up time 5 yrs.
Study: Non comparative direct restorations	**Limitations and applicability to clinical practice**	**Commentary**
(Hansen and Asmussen, 1990)	Thickness of remaining tooth structure is not recorded. Old study (1990), amalgam is not widely used anymore. Study conducted in general practice and therefore results are generalisable.	Good long-term data, more information on patient characteristics needed.
(Deliperi, 2009)	Short follow up period, inexperienced clinician, only molar teeth included, small sample size. Technique sensitive treatment, not all dentists are able to place this restoration (training needed). No information on where study was conducted.	Longer follow up required as very short follow up. No statistical analysis.
(Shafiei, Memarpour and Doozandeh, 2010)	Limited information on amount of tooth structure remaining, limited information about confounders, small sample size.	Promising results but a longer follow up period required.
Study: Non comparative indirect restorations	**Limitations and applicability to clinical practice**	**Commentary**

(Chrepa *et al.*, 2014)	No blinding of clinicians. Experienced clinicians. Lack of power calculation. Limited information on opposing teeth.	Good results. Longer follow up needed.
(Dias *et al.*, 2018)	No blinding of clinicians. Experienced clinician was operator and assessor. Lack of power calculation, better randomisation technique needed.	Promising results but needs a longer follow up time.
(Bindl and Mörmann, 1999)	No patient characteristics mentioned. Very small sample size and, as a result, no statistical analysis. No mention of remaining tooth structure	Excellent success rate but results to be interpreted with caution due to limited information on the teeth involved and small sample size.

Chapter 4

4.1 Introduction

The role of the coronal restoration in the success of endodontic treatment has been discussed in depth in Chapter 3 with the systematic review. Previous studies have shown that the quality of the restoration to be more important in producing less periapical inflammation when compared with good endodontic treatment (Ray and Trope, 1995; Aquilino and Caplan, 2002; Ng *et al.*, 2008). It is therefore very important to have a good quality restoration on a root filled tooth in order to maximise endodontic success. Currently in the U.K. there is no information on how, or what factors affects the dentist's decision-making process choosing the type of coronal restoration on root filled posterior teeth. There is also no information on the dentist's thoughts and perceptions around restoring root filled teeth, research is also lacking on the cost of endodontic treatment, the longevity of restorations in root filled teeth and how patient's paying status affects the choice of restoration they receive.

4.2 Root canal treatment in the U.K.

General dental practitioners (GDPs) In the UK, mainly provide root canal treatment either privately or on the NHS. With the exception of a small proportion of treatment provided by specialist endodontists who generally work on a private basis in specialist practice or in hospital. In 2018/19 in England there were more than 500,800 endodontic treatments provided by NHS general dental practitioners alone (NHS Business Service Authority Dental Practice Division Digest of Statistics). The number of root

treatments provided privately hasn't been reported on. A proportion of these teeth are likely to be posterior teeth that will require restorations.

4.3 The current evidence

A survey of general dental practitioners' approach to the restoration of the root filled tooth was done in 1995 (Hussey and Killough, 1995). This was carried out in Northern Ireland and focused on the GDPs methods of restoring endodontically treated teeth. This survey was investigating whether GDPs routinely provided posts for root filled teeth. There was no information about the thoughts process when it comes to restoring root filled teeth, nor was there any information on the factors which influence dentists to provide a direct or indirect restoration for root filled teeth. The overall conclusion was that the researchers felt that GDPs in Northern Ireland had a sound understanding when it came to restoring root filled teeth, but this was more related to the provision of a post in root filled teeth.

A similar survey was performed on GDPs in Manchester U.K. (Seow, Toh and Wilson, 2003). This study similar to the previous study focused on Dentists thoughts on placing posts in different teeth and materials used to build up the core. They were asked, which type of final restoration they routinely placed in root filled posterior teeth and how long they waited before providing the final restoration. The majority answered, metal ceramic crowns and 1-2 weeks respectively. The conclusion of this study like the previous one felt GDPs had a sound understanding of how to restore root filled teeth. This survey did not use clinical scenarios regarding the patient and their dental status which would have helped the dentist make decisions of how to restore the root-filled posterior tooth.

A survey of general dentists in India, sought their opinion on restoring the root filled anterior tooth and showed that the participating dentists believed that root filled teeth are prone to fracture (Ratnakar *et al.*, 2014). This belief has been also supported by a previous review paper (Tait, Ricketts and Higgins, 2005; Bitter *et al.*, 2010). The factor that influenced the dentist's decision to restore the tooth was the amount of remaining tooth structure. However, with this study being focused on anterior root filled teeth most of the emphasis was placed on post placement, there was no insight into patient factors or economic factors that could influence their decisions.

A similar study was undertaken in Saudi Arabia, which looked at the knowledge, attitudes and practice of general dentists when restoring root filled teeth (Akbar, 2015). Similar to the previous study conducted in India, this study looked at anterior teeth and the conclusions drawn where that the dentists had sound knowledge on how to restore the root filled anterior tooth especially when it comes to material selection and techniques but didn't understand the reasons for placement of a post. Although, this study didn't look at posterior teeth it was interesting to see that there was a lack in basic concepts, which could be a training issue. The design of the survey in both of the above studies were multiple-choice closed ended questions. Questions in this format does not allow participants to express their views. A combination of open and closed questions would be much more appropriate to get a deeper understanding of the dentist's thoughts.

From the previous research it is clear that there is a lack of knowledge on the factors that may influence the dentist's decision-making when restoring the root filled posterior tooth. There have been attempts of surveys being

used to gather information, however, these have been limited to closed ended questions giving limited information.

4.4 How dentists are remunerated in the NHS Dental services

Monetary factors can be key in decision making and therefore it is important to understand how payment for dental treatment works in the United Kingdom to appreciate its impact on deciding which type of restoration is used on root filled posterior teeth.

NHS dental services in England and Wales introduced a contract currency termed the 'unit of dental activity' (UDA) in April 2006. This system replaced the old fee per item and capitation fee arrangements. The latest contract is a system that measures dentist's activity. Under this system the dentists work in a cash limited system, and in return they provide units of dental activity knows as UDAs based on three charge bands related to the complexity of treatment. UDAs are the unit of currency for measuring the type of clinical activity performed by dentists within a 12-month contract for an agreed financial value (Steele, 2009).The financial value of a UDA varies between dental practitioners as a consequence of a decision to use a 12-month 'test' period during 2004–2005 as the basis for calculating dentists' annual salaries. Differences in the volume and type of dental treatment activity conducted during this reference period have resulted in the financial value of one UDA typically ranging between £17 and £40 (Steele, 2009). The UDA has attracted much criticism from dental practitioners who cite inequity regarding variable UDA rates and a target-

focused mentality which has often resulted in anxiety regarding the financial implications associated with contract underperformance(Hudson, 2007). This is very different to private dentistry where each item of treatment will have a fee, similar to the old NHS ‘fee per item’ system (Steele, 2009).

The UDA system has been controversial, with many dentists feeling that the UDA system was unfair (Milsom *et al.*, 2008). A previous survey of happiness between NHS dentists working in the UDA system versus private dentists showed private dentists were much happier than NHS dentists especially when it came to job satisfaction and being able to provide time to their patients. A huge majority of NHS dentists, 91%, did not feel they were fairly remunerated and 89% felt unable to carry out the work they do without feeling overly stressed and 85% do not feel the level of job satisfaction they would like to. In contrast with the experience of private dentists showed that 85% were happier about the remuneration they receive, 81% happier about being able to work without feeling overly stressed, and 89% happier about the level of job satisfaction they can achieve (Jones, 2018).

NHS Dentistry in Scotland and Northern Ireland hasn’t adopted the UDA system. They still operate under the ‘old' system where patients are registered under a capitation or continuing care arrangement with the dentist, who is then paid a fee per item of service. The patient if not entitled to free treatment and the patient has to pay 80% of the dentist’s fee (*Health service dental charges and treatment*, 2018). There is no information in the literature regarding NHS dentist’s happiness in Northern Ireland and

Scotland regarding the fee per item system and is therefore difficult to compare with England.

Dentists are ethical professionals and work in the best interest of their patients. The General Dental Council (GDC) standards guidelines suggest that patients expect that their interests will be put before financial gain and business needs and the dentists role is to put patients' interests before their own or those of any colleague, business or organisation (Vital, 2006). Dentists are bound by these standards and therefore must be putting their patients' wellbeing at the forefront of their decisions regardless of any shortcomings of any system they are a part of. Bearing this is mind and given the multifactorial issues such as tooth condition, remuneration, patient choices, and the limited clinical evidence for effectiveness of restoring a root filled posterior teeth with direct or indirect restorations. This may result in variability in the care delivery and outcome of care.

4.5 Summary

The results of the systematic review in chapter 3 showed limited evidence for the effectiveness of direct and indirect restorations for restoring root filled posterior teeth without posts. This then poses the question, if there is very limited evidence how are dentists making their clinical decisions when it comes to restoring root filled posterior teeth? There is also a lack of information about the factors that influence clinical decision-making for restoring root filled posterior teeth.

4.6 Use of Surveys in Research

Using surveys in research is a common in health and health service. Survey research is well applied in social research. The term 'survey' can be used in a variety of ways, but generally refers to the selection of a relatively large number of people from a pre-determined population i.e. the population of interest, which in this case is General Dental Practitioners. This is followed by a relatively small amount of data from those individuals. This collected data is used to make some inference about the wider population from the sample of individuals (Kelley *et al.*, 2003).

Data is gathered in a standardised form. It can take the form of a questionnaire or interview. Surveys are designed to provide a 'snapshot of how things are at a particular time'.

As with any research method there are advantages and disadvantages to survey research, these are as follows: (Electronic, 2014).

Advantages:

- The research produces data based on real-world observations.
- The breath of coverage of many people or events means that it is more likely than other approaches to obtain data based on a representative sample, and as a result can be generalised to a population.
- Surveys are able to generate a large amount of data at a low cost and a relatively short time frame.

Disadvantages:

- The data produced are likely to lack details or depth on the topic being investigated.
- Securing a high response rate to a survey can be difficult , especially if the survey is carried out by post or by telephone.
- The significance of the data can become neglected if the researcher focuses too much on the range of coverage to the exclusion of an adequate account if the implications of those data for relevant issues, problems, or theories.

The survey approach can cover a variety of methods to answer the research question. Surveys can be delivered to potential participants in different ways, these include postal questionnaires, online questionnaires, face-to-face interviews and telephone interviews.

4.6.1 Vignettes in research

Medical education has used the clinical case as a teaching tool since William Osler advocated bedside teaching at the turn of the 19th century, and probably long before (Osler W, 1903). Vignettes can be described as stories about individuals and situations that make reference to important points in the study of perceptions, beliefs and attitudes (Hughes and Huby, 2004). The combination of the vignette technique with a traditional survey is a promising but too infrequent used research method for investigating respondent's beliefs, attitudes and judgement (Atzmüller and Steiner, 2010).

Vignettes have been used widely to address research questions related to interpretation of actions, decision-making, and physiological constructs such as perceptions, attitudes and beliefs. Generally vignettes are more likely to be effective when they engage participants' interest, which are relevant to people's lives, and appear real (Hughes and Huby, 2004). Responses may be elicited through closed and forced choice responses. Closed ended questioning tends, although not exclusively, to be employed with quantitative applications of vignettes. For example, factorial surveys employ a closed series of responses to aid quantification and sometimes participants are invited to rate responses along a scale (Faia, 1980). However, closed questioning may not capture, as much as open-ended questioning, and the socially situated elements of participants' responses. Open-ended questioning has been shown to have considerable value in vignette studies (Sheppard and Ryan, 2003). Sumrall and West (1998) (Sumrall and West, 1998) used open-ended questions to promote individual creativity amongst participants when responding to vignettes, and that open ended responses may provide a more realistic estimate of reactions to real life situations. Vignettes using closed ended questioning, notably in surveys (Wagenaar *et al.*, 2001), allow for a broad range of variables to be incorporated into the vignette research design.

Previous studies that have used vignettes to explore decision making of dentists in reporting child abuse (Adair *et al.*, 1997). Vignettes have also been used in patient involvement in decision making and pain management in dentistry (Gilmore, Sturmey and Newton, 2006; Chambers, Mirchel and Lundergan, 2010). More recently a study was done about diet

diaries in general dental practice in England (Arheiam *et al.*, 2016), as well as a study which looked at the management of caries in first molars (Taylor, Pearce and Vernazza, 2019).

4.6.2 Research Question

What are the factors and perceptions that influence the decision-making process of general dental practitioners (GDPs) when restoring root filled posterior teeth (molars and premolars) with direct or indirect restorations?

Aim

To investigate the factors and perceptions that impact on GDPs decisions to restore a posterior root filled tooth with a direct or indirect restoration.

Objectives

- Explore the attitudes and confidence of GDPs providing treatment in the private sector compared with those working in the NHS to restoring a posterior root filled tooth with direct or indirect restoration.
- Identify the factors which GDPs may take into consideration when deciding which type of restoration to place and determine which factors are more important to GDPs
- Assess the time interval for the GDP to place a final restoration on a root filled posterior tooth.

4.7 Methods

4.7.1 Study design

This study was a cross-sectional observational electronic survey distributed to GDPs to investigate the factors and perceptions that affect GDPs working in the U.K, when making decisions on how to restore a root filled posterior tooth with a direct or indirect restoration. The survey included three case-based vignettes.

4.7.2 Ethical approval

Ethical approval was granted in December 2018 from the University of Liverpool (Ethics number 3921), (Appendix 3)

4.7.3 Target population

The questionnaire was piloted for clarity and content validity. A sample of 8 GDPs working part time at Liverpool University Dental Hospital were chosen to fill out the survey. None of these dentists were on any specialist list. They were asked to fill out the survey and give feedback. On the survey there was a space for the dentists to give their feedback in writing. There was a variety of questions regarding how the dentists felt about the pilot survey. Most of the feedback given was related to the length of the questionnaire and the lack of pictures accompanying the scenarios. The dentists felt the survey was too long and they wanted to write less for their answers. There was a preference for a more multiple-choice answer format where the answer was already given and the box, they felt most similar to their answer had to be ticked. After reading the analysing the feedback

appropriate changes were made. The participants who were involved in the questionnaire were asked not to take part in the main survey.

There were 41096 registered dentists with the General Dental Council. The general dental practitioner restores the vast majority of root filled posterior teeth. These dentists work either in private, NHS or mixed practices. Therefore, the target population of this study was general dental practitioners (GDPs) practicing in the U.K who are registered with the General Dental Council (GDC). Practioners will be randomly selected from practices NHS and Private, in different regions of the U.K., North of England, South of England, Midlands, Scotland, Wales, Northern Ireland, and London. The NHS system in Scotland and Northern Ireland is similar to the previous system in England of fee per item and haven't yet adopted the UDA system. Given that there are no previous studies to the author's knowledge in this subject area using this methodology hence the sample size was calculated based on a previous study conducted by GDPs looking at diet diaries (Arheiam *et al.*, 2016), together with the help of a statistician.

4.7.4 Sample size

A target sample size of 400 was decided, as this will give 95% confidence intervals of +/- 5%. 400 is an achievable sample size to target for the DDSc programme however as the response rate will not be 100%, it is likely that the 95% confidence interval will be wider than +/- 5%. A response rate of 25% (sample of 100) would give a confidence interval of +/- 10%.

4.7.5 Survey format

The design and the hosting of the online survey was carried out using a digital programme Qualtrics XM 2018.

The survey allowed answers in many formats such as text entry, multiple choice, or a drop-down menu of options.

The survey was formatted to be able to be used on a variety of digital devices such as smartphones, tablets and computers.

4.7.5 Invitation letter

The invitation letter was attached to the email and the online link (Appendix 4). The letter provided information about the title of the study, the aims and objectives and the instructions on how to participate in the survey. The responders were reassured about anonymity of the data and gave them an opportunity not to participate in the study.

There was no written consent, and the participants gave consent by opening the link and beginning the survey. All participants were able to withdraw from the study at any point. The consent forms were pre-read for clarity and suitability by GDPs working at Liverpool University Dental Hospital.

4.7.6 Mode of Survey Distribution

The survey was distributed from December 2018 to February 2019. The survey was distributed by contacting dentists in the U.K working in general practice by email at their practice address and they were invited to participate in the survey. The email contained a copy of the invitation letter

and a link for the dentists to open and complete the survey. Two email reminders were sent one at two weeks after the initial email was sent and one at 28 days. GDPR was followed and the email addresses were available via registered companies who have clearance to provide addresses for those dentists who had agreed to be contacted.

A survey link was also posted on social media forums where dentists discuss dental matters in the U.K. A link was given for the subscribers to take part in the survey. The invitation letter was attached to the link. The survey was completely anonymised and therefore the author was not able to identify the participants.

4.7.7 Anonymity and confidentiality

The collected data for the research was treated as confidential material. The identification of the participants was anonymised. No names were collected, nor the email addresses stored. All participants who answered the survey were given a unique code, which was stored on the survey database software, but the participant couldn't be identified to maintain anonymity.

4.7.8 Survey Design

The survey was divided into 4 sections (Appendix 5)

- Section 1

This section asked demographic information regarding the GDPs place of graduation, number of years qualified, qualifications other than primary qualifications, sector of current work, number of root filled teeth restored

per month, how confident they feel when restoring root filled posterior teeth, and thoughts on how they felt about their undergraduate training with regards to restoration of the root filled posterior tooth.

- Sections 2, 3 and 4

These were case vignettes, where a photograph of a root filled tooth was shown accompanied by a clinical scenario. The questions related to the management of the root filled tooth.

4.7.9. Data analysis

Descriptive statistics were used to summarise numerical data such as the distribution and participant characteristics of the study sample. All of the data was exported into SPSS 24 and Microsoft Excel 2015. Free text box answers were analysed for their answers until saturation.

4.8 Results

4.8.1 Survey response

The majority of the responses were collected from the online social media link. The total number of responses was 528. The response rate from emails was very poor as only a limited number of surveys sent via email were completed. More surveys were completed using the online link. However, it is impossible to know how many links were sent as on social media links can be shared by other participants and there is no way of monitoring this and therefore a response rate cannot be calculated. Table 10 shows the distribution.

Distribution Channel	**Audience size**	**Responses**	**Completion rate**
Invite over email	777	49	6.3%
Social media link	N/A	479	N/A

Table 10. Distribution of surveys

4.8.2 Demographics

4.8.2.1 Country of qualification

The majority of the participants qualified in England. Northern Ireland and Republic of Ireland had the lowest number of representatives. Figure 2 below shows the distribution of the participants.

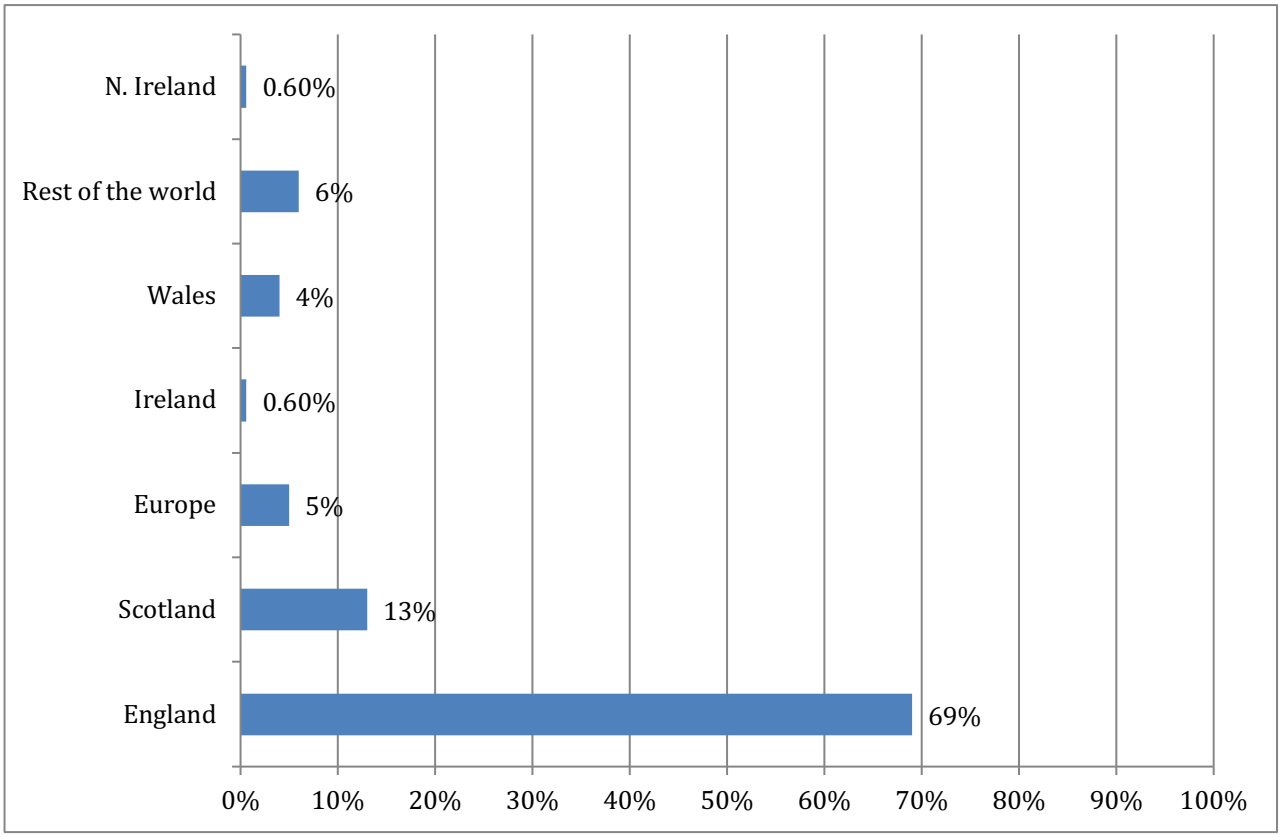


Figure 2. Country of qualification of participants (GDPs)

4.8.2.2 Number of years qualified, qualifications held, sector of work and place of work in the U.K.

The number of years that the participants have been qualified can be seen in Figure 3. Figure 4 shows the percentage of dentists that held further qualifications other than their primary BDS degree nearly a third of the participants didn't hold any further qualifications. Figure 5 shows the distribution of dentists that work in NHS, private and mixed practices. The spread seemed to be quite even amongst all sectors. The vast majority of participants in this survey worked in the north of England. Figure 6 shows the distribution.

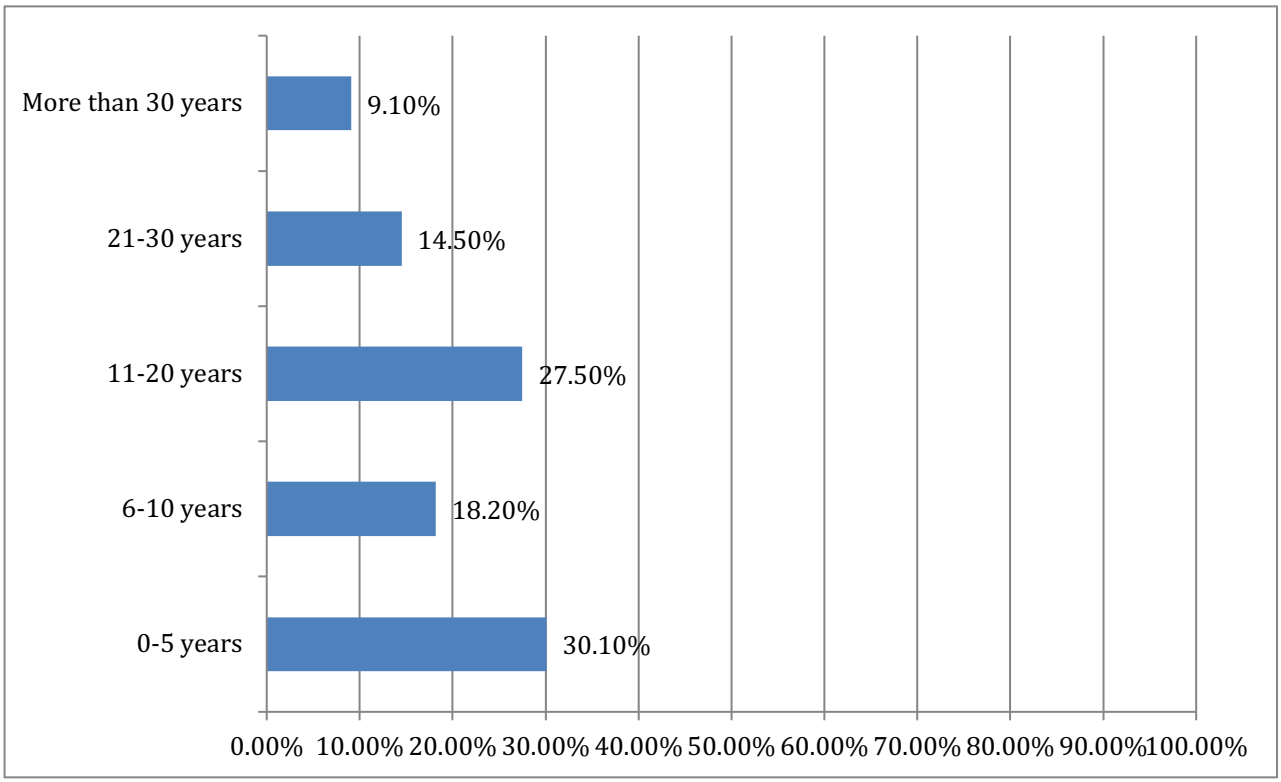


Figure 3. How many years have you been qualified?

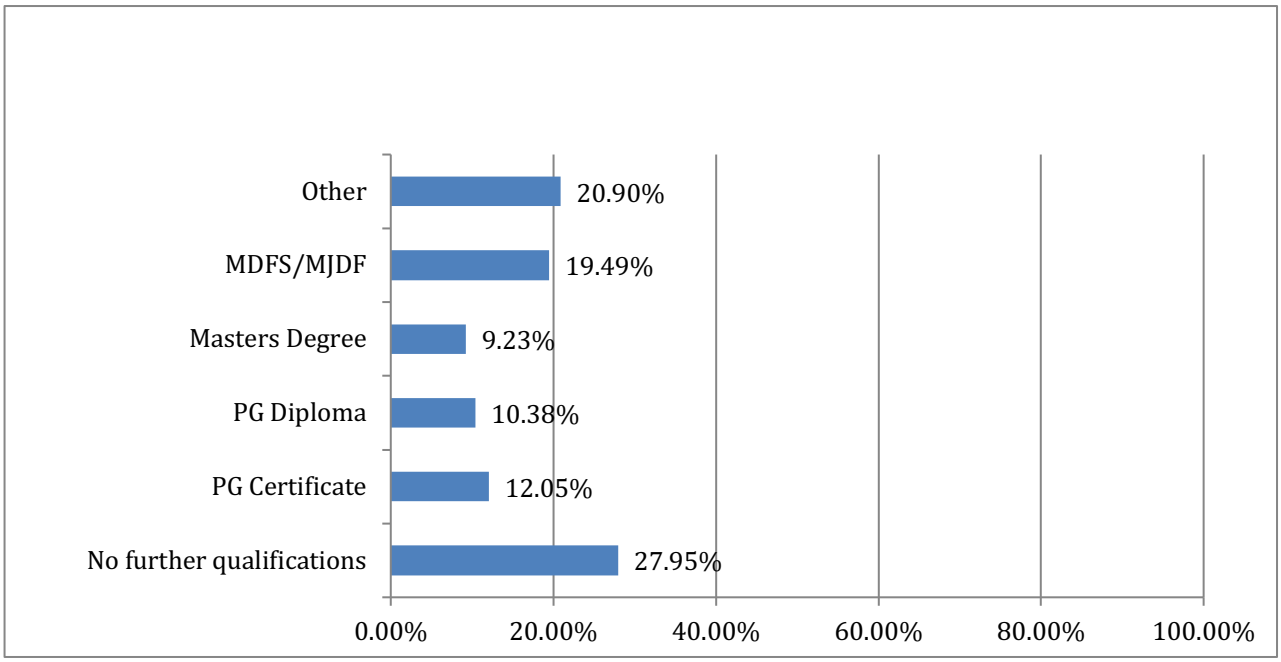


Figure 4. Qualifications other than BDS

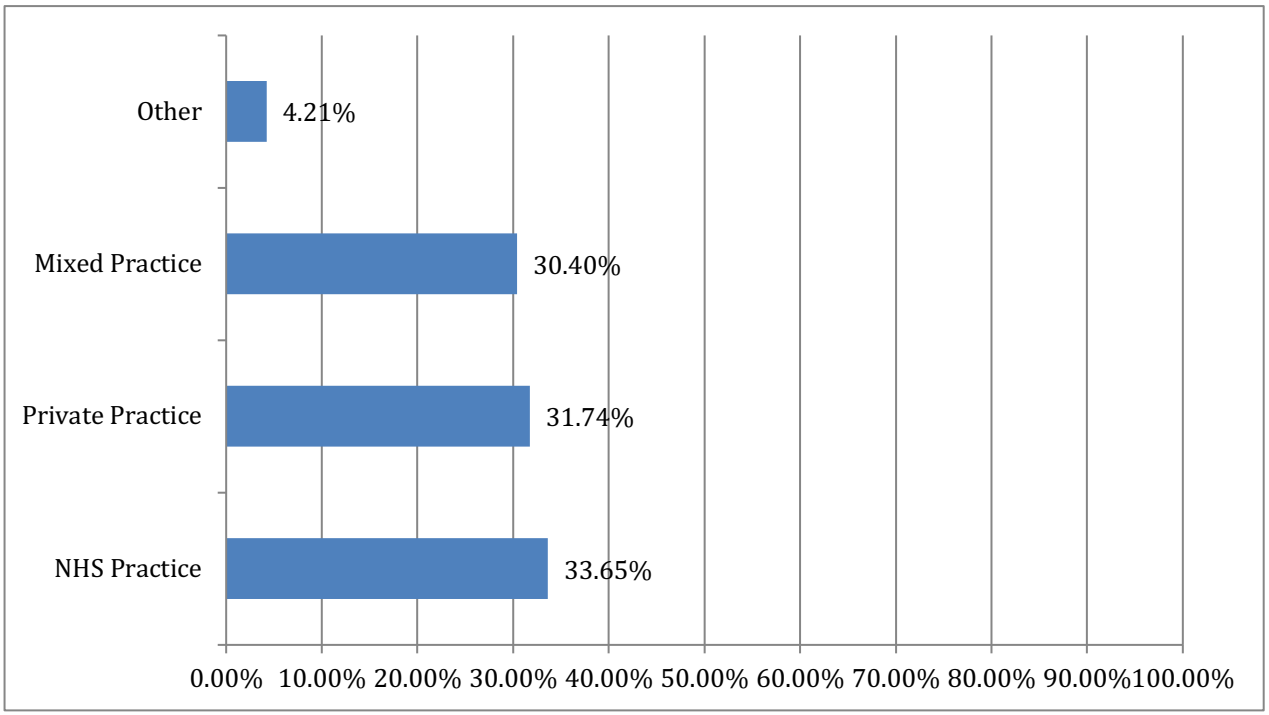


Figure 5. Where the GDPs predominantly work

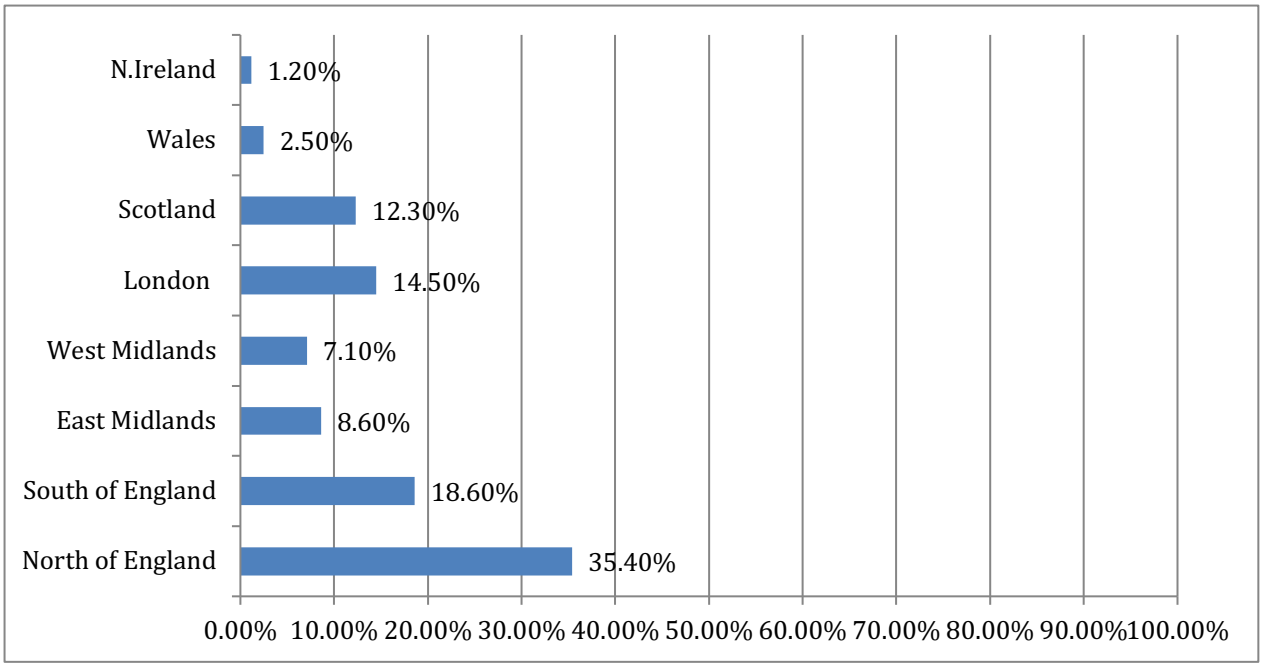


Figure 6. Which part of the U.K the GDP work?

4.8.2.3 Number of root filled teeth per month, type of restoration used for root filled teeth.

Figure 7 shows the average number of any root filled teeth restored per month by the GDPs. 60% of GDPs restored between 0-5 teeth per month. The most common restoration for GDPs to place on root filled teeth was an indirect restoration, this can be seen in Figure 8.

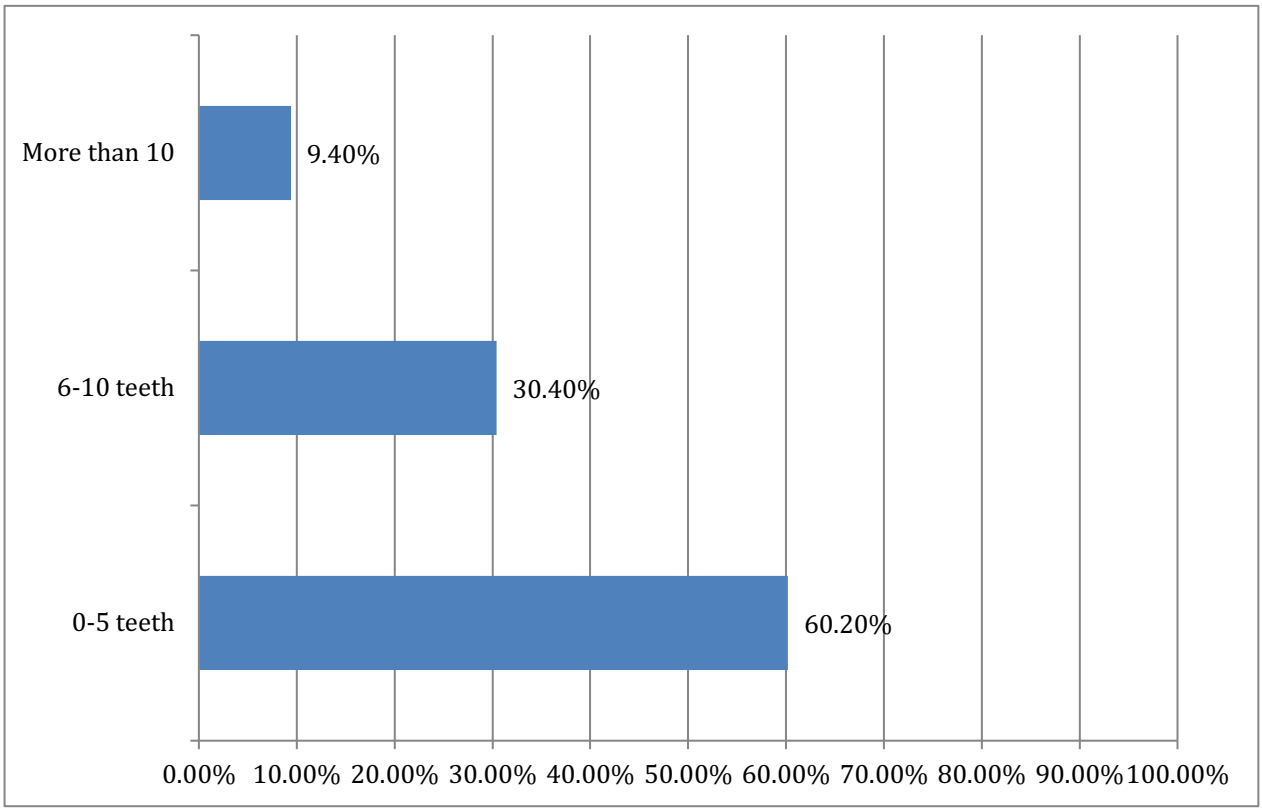


Figure 7. Number of root filled teeth per month

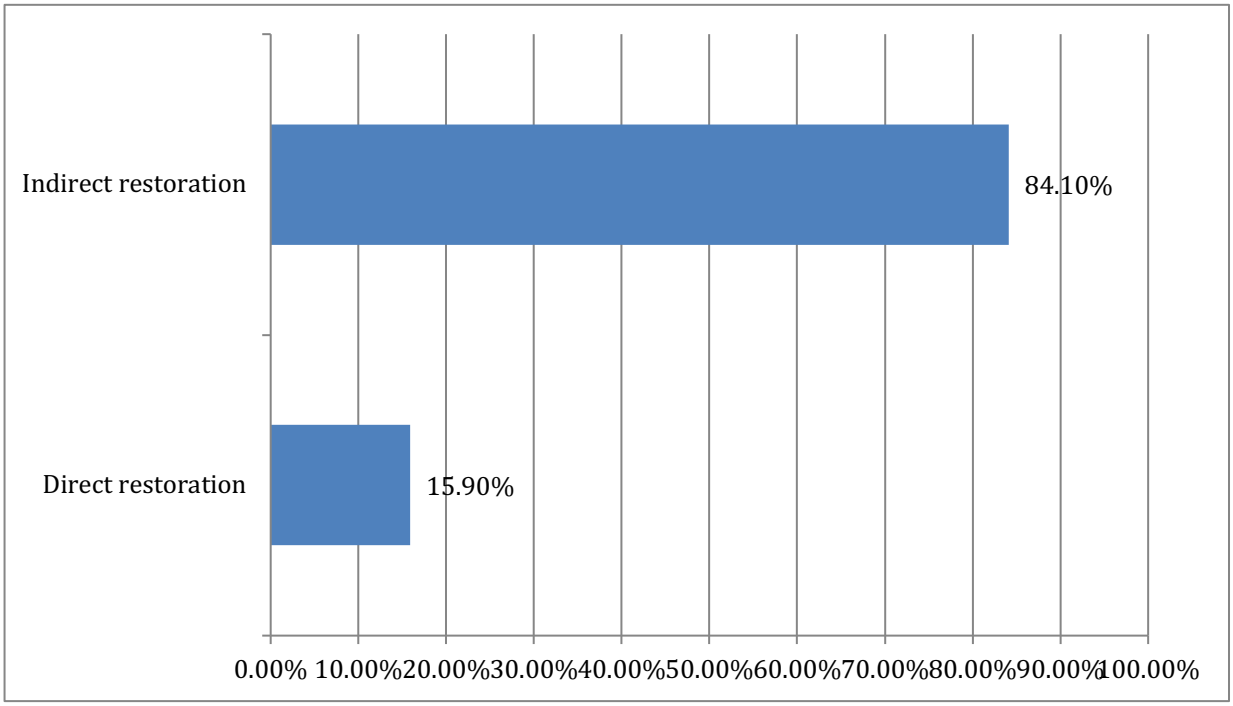


Figure 8. Type of restoration used for root filled teeth

4.8.2.4. GDP's undergraduate training experience.

The GDPs gave mixed feelings regarding how sufficient they felt their undergraduate training was regarding restoring root filled posterior teeth. The distribution is shown in Figure 9

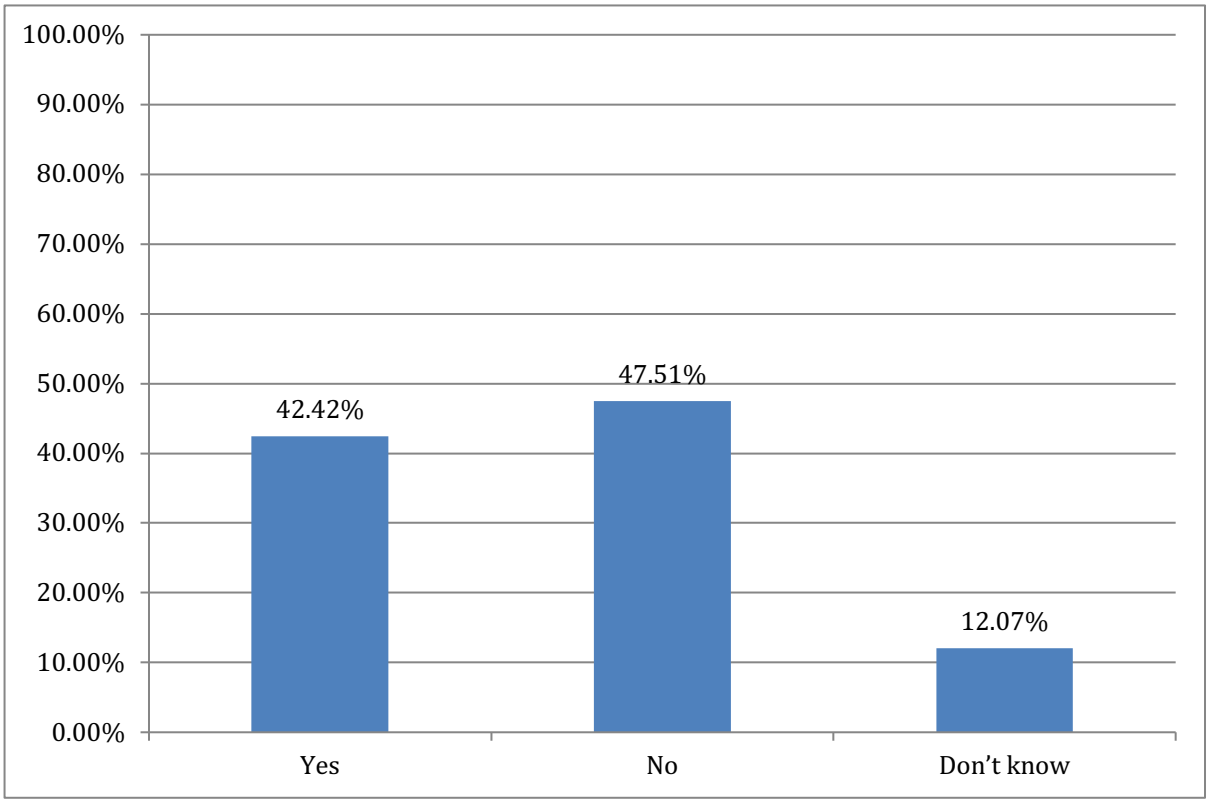


Figure 9. Do GDPs feel sufficiently trained as undergraduates to restore root filled posterior teeth

4.8.2.5. Confidence to restore root filled teeth compared with the number of years qualified

The trend between the number of years qualified and the confidence of the GDPs to restore root filled posterior teeth is shown in figure 10. This graph indicates that confidence of GDPs increased as the number of years qualified increased.

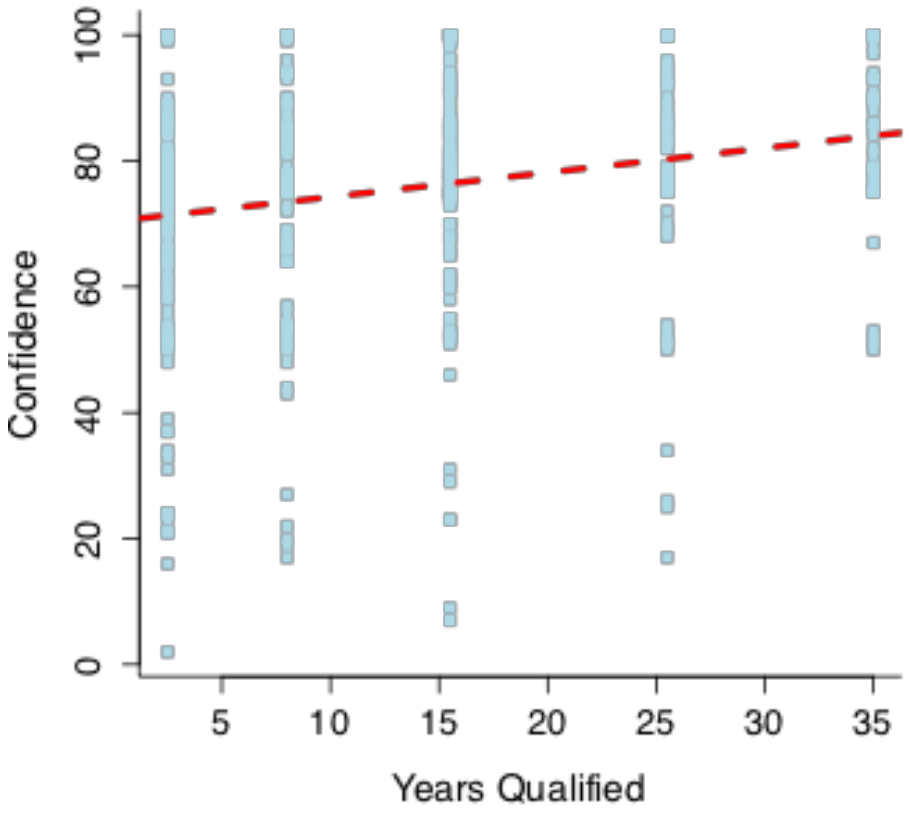
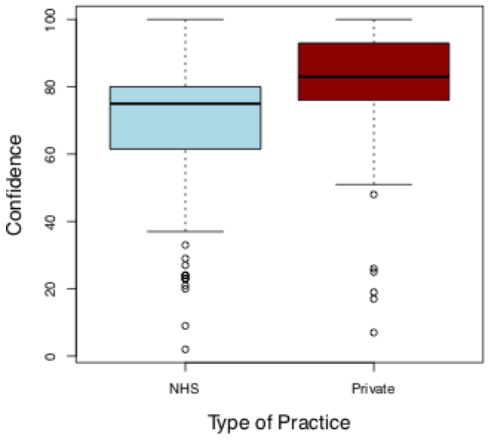


Figure 10. Professional confidence to restore root filled posterior teeth versus the number of years qualified

4.8.2.6. Relationship between confidence to restore root filled teeth and the type of practice the GDP works in.

The relationship between confidence and type of practice the GDP works in was shown in Figure 11 and displayed as box plots. The null hypothesis was, there is no difference in the dentist's confidence to restore root filled posterior teeth and the type of practice the dentist works in. The box plot showed that private dentists have slightly higher confidence to restore root filled posterior teeth than NHS dentists. This suggests that private dentists are significantly more confident than NHS dentists when it comes to restoring root filled posterior teeth with p value <0.001.



Confidence and Type of practice

Linear Model results

	est (se)	Pval
(Intercept)	69.93 (1.361)	<0.001
nhsPrivPrivate	11.68 (1.954)	**<0.001**

Figure 11. Statistical analysis of confidence versus type of practice

4.8.3 Results for Vignette 1.

Below is a description of vignette 1 (see Appendix 5).

A 21-year-old medically fit and well male patient attends your practice for the restoration of the UR6 which has been root treated. Radiographically the UR6 has a well-obturated root filling to length with no voids and no periapical area.

Previous to root canal treatment the tooth had a sinus and was symptomatic. Presently, the tooth is asymptomatic. Oral examination reveals the patient has a minimally restored dentition and low periodontal risk, class 1 occlusion and no tooth surface loss.

4.8.3.1 Restoration for the UR6.

The results to the questions for this scenario are based on the management of the UR6. The results showed the majority of GDPs preferred to restore the UR6 with an indirect restoration as opposed to a direct restoration. Figure 12 below shows the distribution.

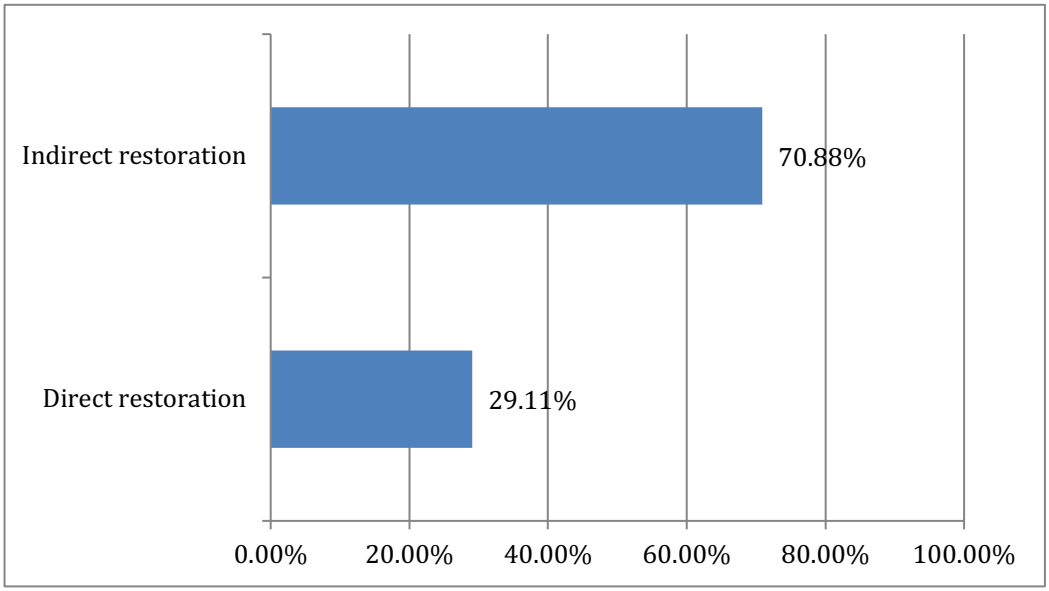


Figure 12. Which restoration would you restore the UR6 with?

4.8.3.2 Restoration choice for the UR6 versus the number of years qualified and the type of practice the GDPs works in

When the restoration of choice was assessed with the number of years qualified it was shown that there was no effect on the choice of the restoration with regards to clinical experience. The majority of GDPs, no matter when they qualified, would restore the UR6 with an indirect restoration, this was the same for private and NHS dentists. The details can be seen in Figures 13 and 14.

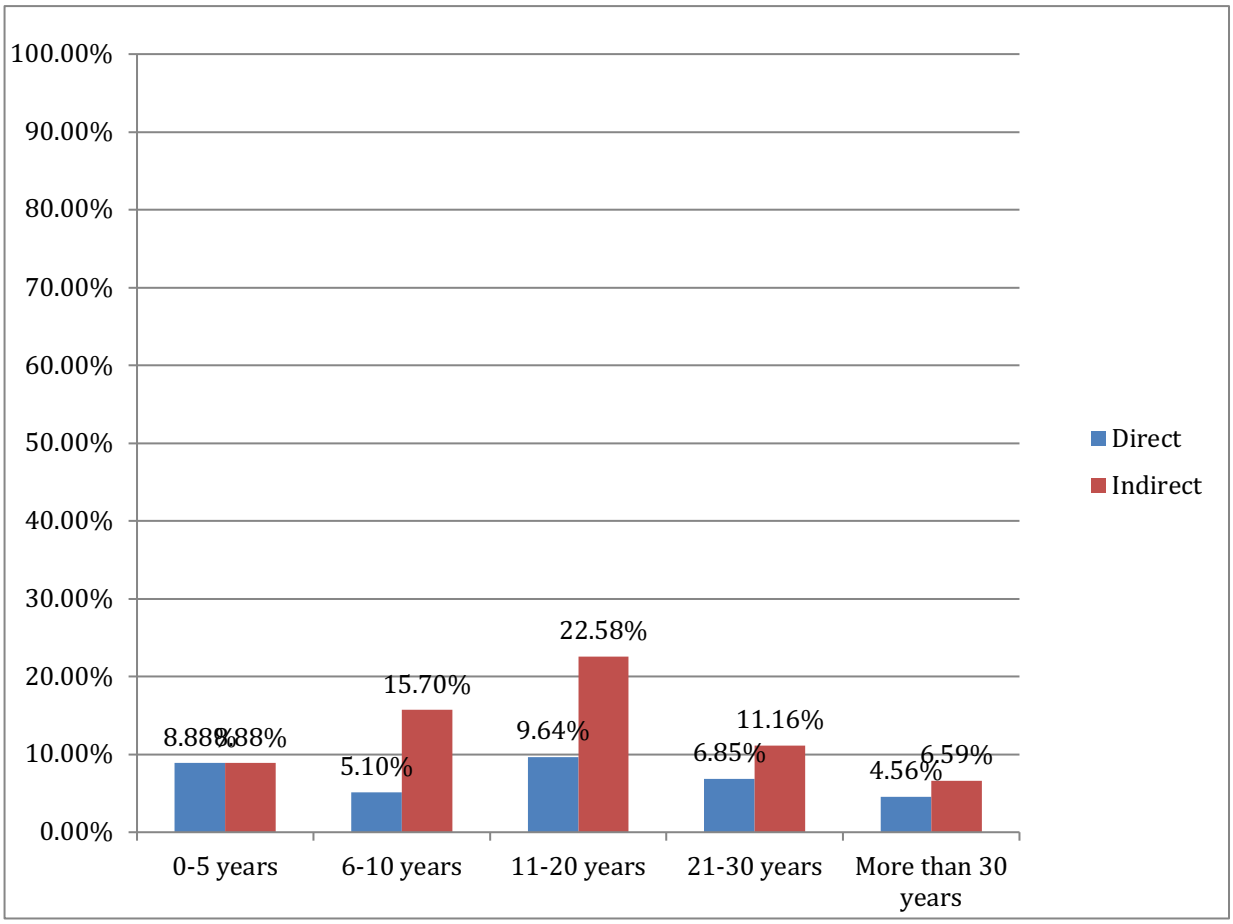


Figure 13. Which restoration would you restore the UR6 with based on the number of years qualified?

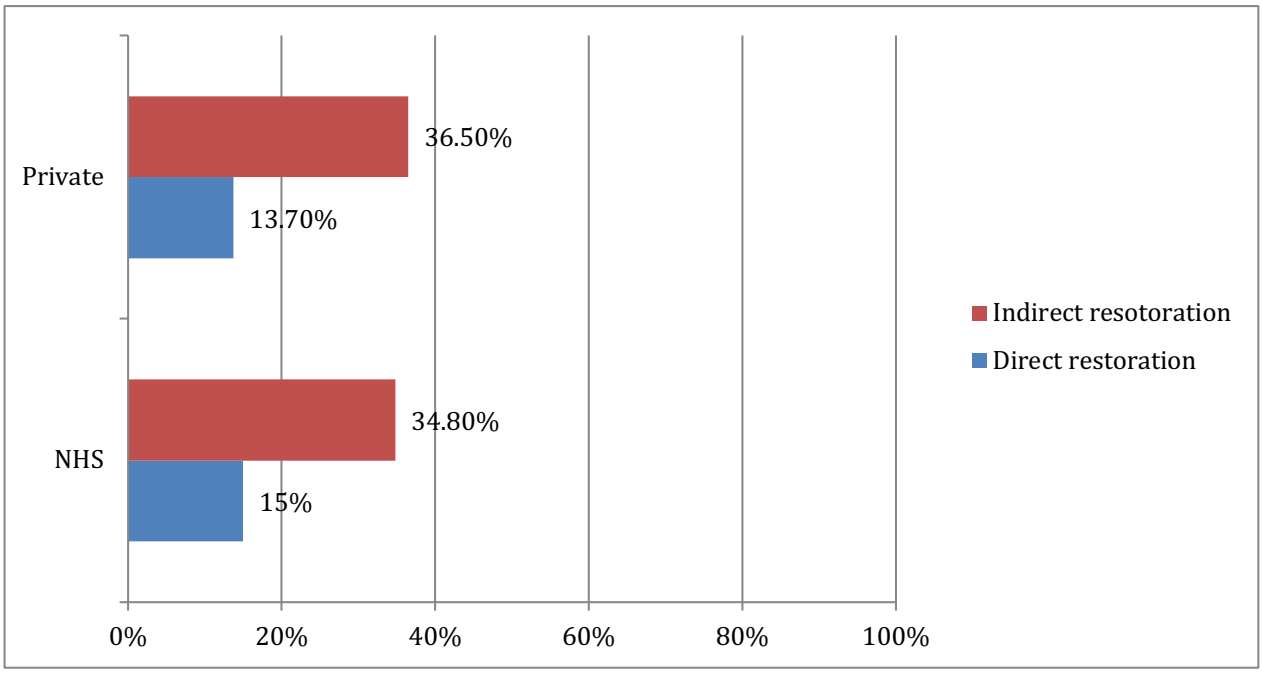


Figure 14. Type of restoration for the UR6 based on the practice the GDP works in

4.8.3.3 Change of management if the patient has symptoms.

The majority of the GDPs felt that their management would change if the patient had persistent symptoms, this can be seen in Figure 15. The reasons for the change in management was asked in a free text box and below in Table 11, the common answers have been analysed and summarised.

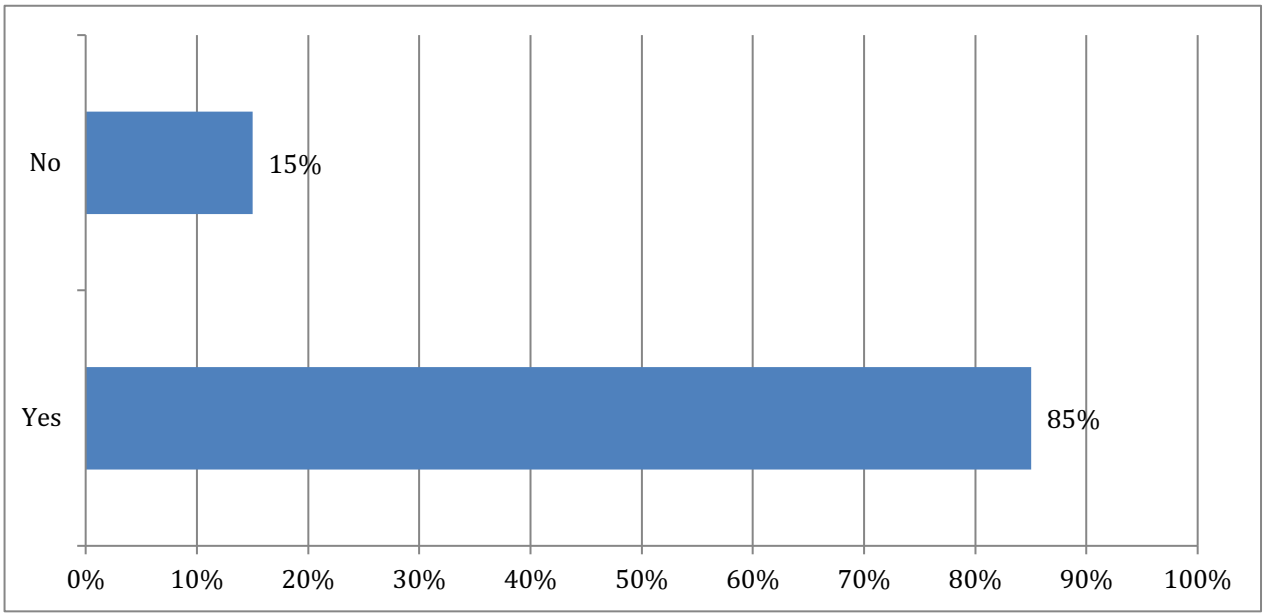


Figure 15. Would your management change if the patient has persistent symptoms? (Vignette 1)

Question.	Summary of free text box answer
'Yes' to change in management if patient has persistent symptoms.	Refer patient. Resolution of symptoms.
'No' to change in management if patient has persistent symptoms	Coronal seal Composite restoration

Table 11. Text box answers for change in management if the patient has persistent symptoms.

Summary from free text answers

GDPs, who answered 'Yes', felt that if the patient continued to be in pain and discomfort, they would be more likely to refer the patient to another clinician or specialist for a second opinion as pain could be from a different origin. Another reason for this was due to the risk of patient complaint and litigation. Some dentists preferred for symptoms to settle before continuing with more treatment.

The GDPs who answered 'No', felt that getting a good coronal seal on the tooth was highly important and wouldn't change their management. The use of composite material was also mentioned in this case to help the dentists to be able to retreat the tooth should symptoms not settle; also, composite material could be used to cover and protect the cusps while waiting for symptoms to settle.

4.8.3.4 Change of management if the patient has high caries risk.

Figure 16 shows GDPs change in management if the patient is high caries risk. 61% said ‘no’ to change in management and 39% of GDPs said ‘yes’ to change in management. 100% of those that said ‘Yes’ did because they preferred to defer the indirect restoration, or they wanted to extract the tooth.

The GDPs that said ‘no’, 100% would continue to place the indirect restoration

The GDPs that answered ‘Yes’ to change in management if patient had high caries risk, 100% of the GDPs opted to defer the indirect restoration.

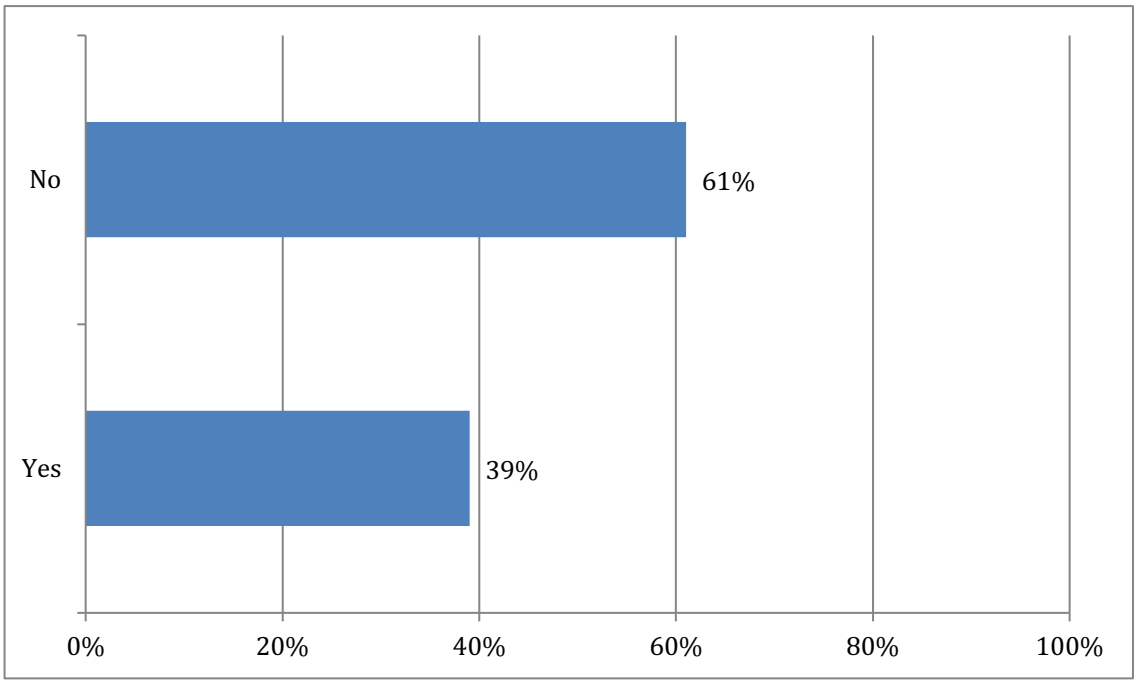


Figure 16. Change in management if patient is high caries risk (Vignette 1)

4.8.3.5 Change of management if the patient is NHS exempt.

The majority of GDPs didn't change their management based on the patient's exempt paying status which can be seen in figure 17. The reasons for the GDP's decisions were asked in a free text box and table 12 displays the common answers.

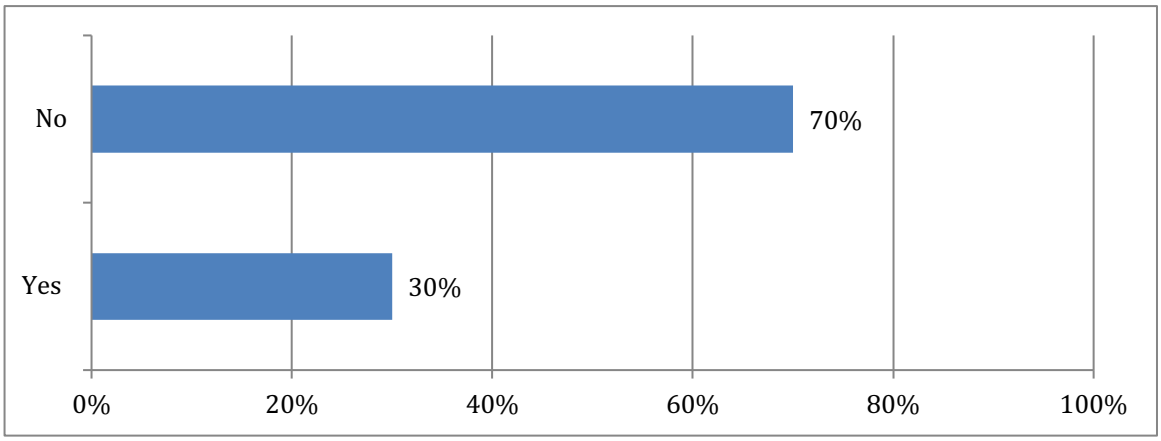


Figure 17 Would your management change if the patient were NHS exempt?

Questions	Summary of free text box answers
'Yes' to change in management if patient is NHS exempt	Low lab costs Patient affordability UDAs (units of dental activity) Profit
'No' to change in management if patient is NHS exempt	No difference between NHS or exempt patients

Table 12. Free text box answers for change in management if the patient were NHS exempt

Summary from free text answers

Dentists discussed financial reasons for their change in management for NHS exempt patients. They felt profit could be increased with patients that were exempt by claiming NHS band 3 treatments. This would help the

dentists reach their UDA targets. Some felt, as the patient doesn't pay then it would be unlikely for them to be able to afford an indirect restoration which would be band 3 if they were paying, and as a result they felt that giving the patient a band 3 treatment would be appropriate. Metal indirect restorations would be more likely provided to NHS exempt patients due to lower laboratory costs.

GDPs that answered 'No", felt that management of patients was irrelevant based on their paying status and all patients should be treated the same.

4.8.3.6 Change of management if the patient wants a private option.

In figure 19 the percentage of GDPs that would change their management if the patient wanted a private option is quite similar. The common reasons for 'Yes' and 'No' answers are displayed in table 13.

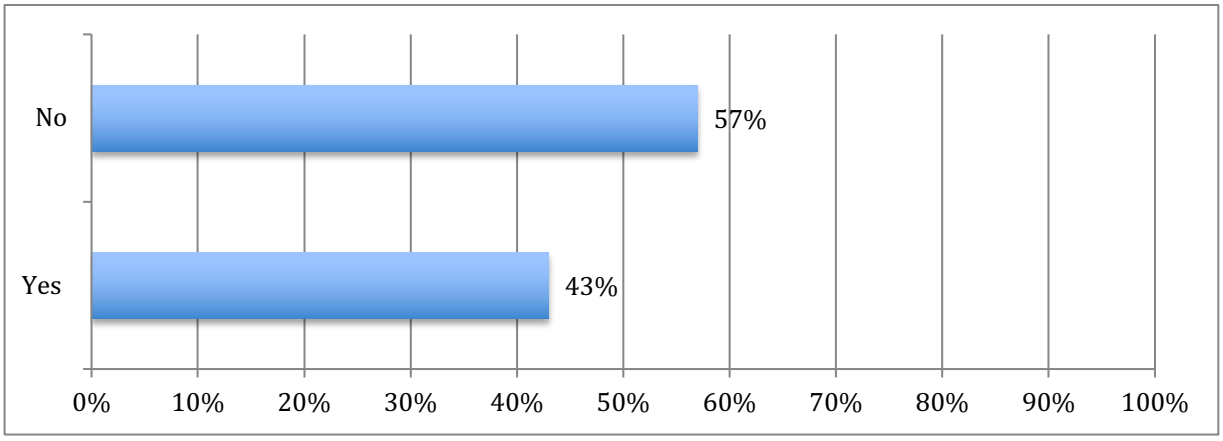


Figure 18. Would your management change if the patient wanted a private option?

Questions	Summary of free text box answers
'Yes' to change in management if the patient wants a private option	Lab costs Material quality Choice of restoration Profit
'No' to change in management if patient wants a private option	No difference between NHS or Private patients

Table 13. Text box answers for change in management if the patient wanted a private option.

Summary from free text answers

GDPs felts patients that requested a private option then they would have more choice of restorations to offer the patient, able to use better quality materials and as patients will be charged a higher fee than NHS fees the profit margins would be greater. They felt the patient giving dentist more freedom to treat would cover lab costs.

The GDPs that said 'No', didn't feel there was any difference between private and NHS treatment options. They felt that any decisions that are made to treat should be made according to the tooth in question and not be influenced by financial reasons.

4.8.4 Results for Vignette 2

Below is a description of vignette 2 (see Appendix 5).

An 18-year-old fit and well female patient had root canal treatment on the LR6 due to irreversible pulpitis. Oral exam reveals the patient has an **anterior open bite**, good oral hygiene and good periodontal health. Radiographically the LR6 is well obturated to length in the mesial roots, the obturation is 3mm short in the distal root but has no periapical lesion.

4.8.4.1. Timing and type of restoration for the LR6

How long the GDPs would wait to place the definitive restoration on the LR6 based on the practice that they work in is shown in Figure 20. 34% of dentists which includes NHS and Private practioners would restore the tooth definitively immediately after obturation of the tooth. The results are very similar between NHS dentists and private dentists when it comes to the choice of restoration for the LR6 this can be seen in Figure 21.

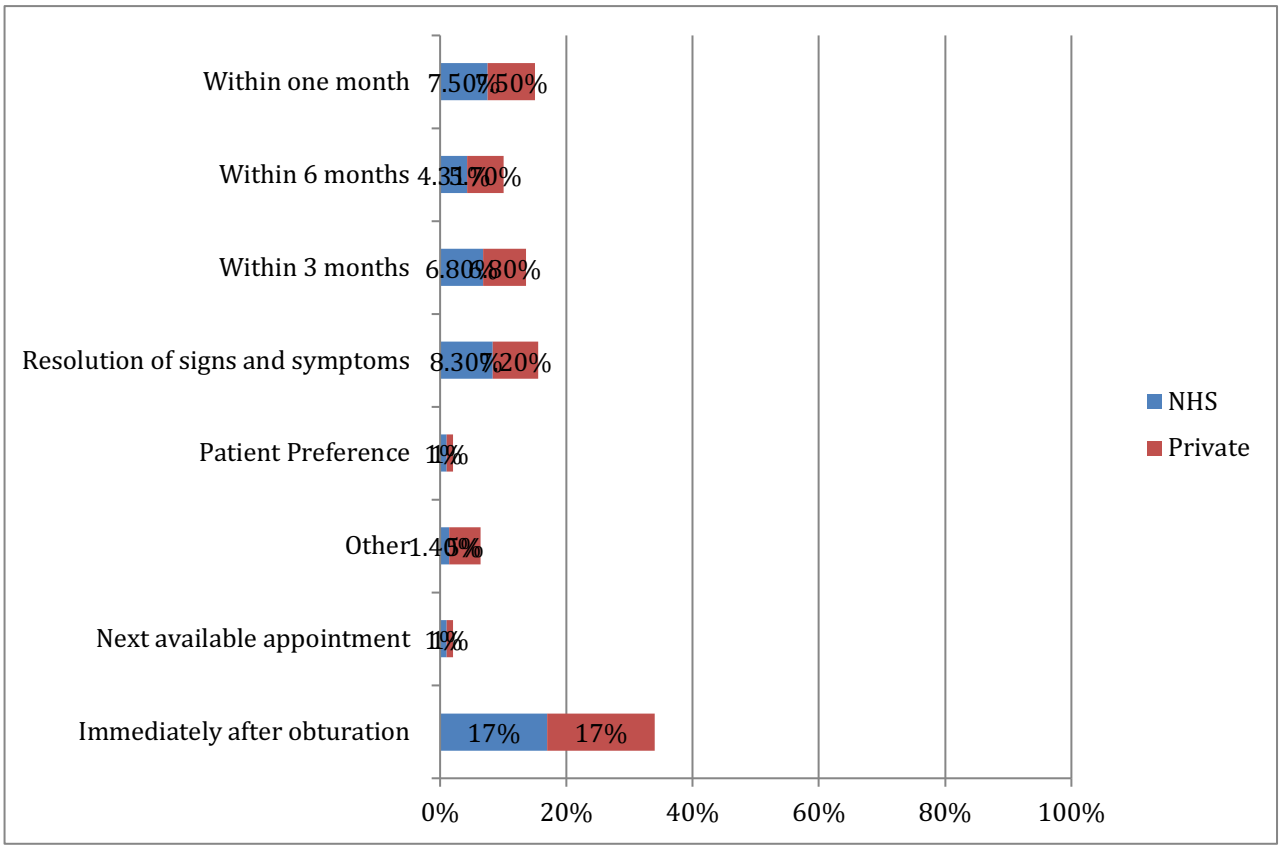


Figure 19. How long would you wait to place the definitive restoration on the LR6 based on the practice you work in?

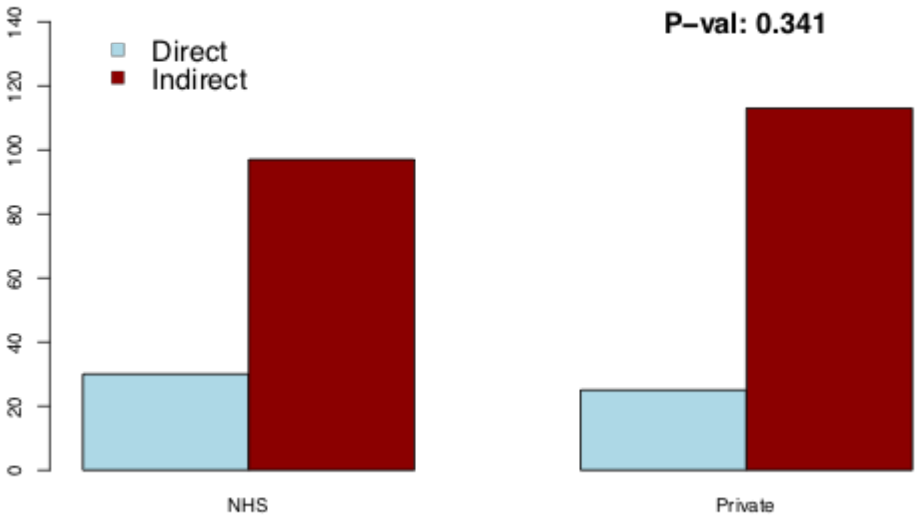


Figure 20. What is the most likely restoration of choice for the LR6 by practice type?

4.8.4.2. Change in management if the patient has a class 1 occlusion and no signs of tooth wear.

In Figure 22 the majority of GDPs that would change their management if the patient had a class 1 occlusion. The common reasons for change in management are shown in table 14.

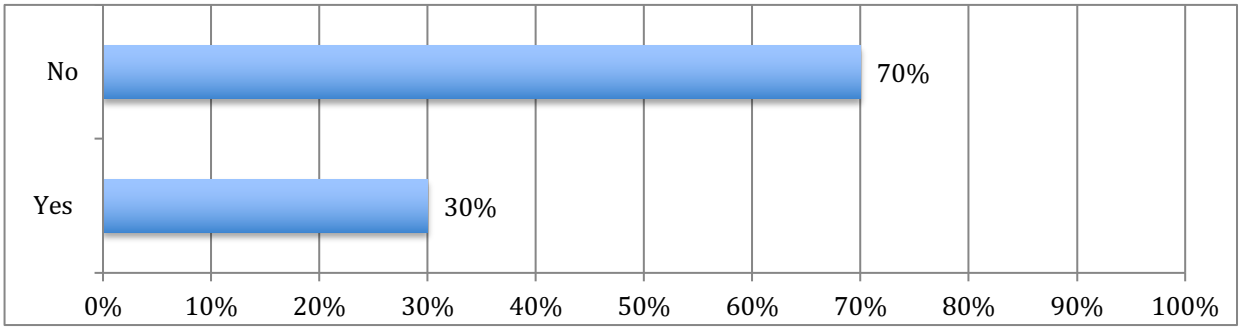


Figure 21. Would your management change if the patient had a class 1 occlusion and no signs of tooth wear?

Questions	Common free text box answers
'Yes' to change in management if the patient has class 1 occlusion	Direct restoration

Table 14. Text box answers for change in management if the patient has a class 1 occlusion.

Summary from free text answers

The dentists who wanted to restore the LR6 with a direct restoration in a class 1 occlusion felt the reasons for this would be the tooth has a minimal access cavity and most of the tooth remaining and the ease of placing a composite restoration was a factor in their decision.

4.8.4.3. Change in management if the patient was NHS exempt.

The majority of GDPs wouldn't change their management based on the patient's exemption status; this is seen in Figure 23. The reasons for the GDP's answers are given in table 15.

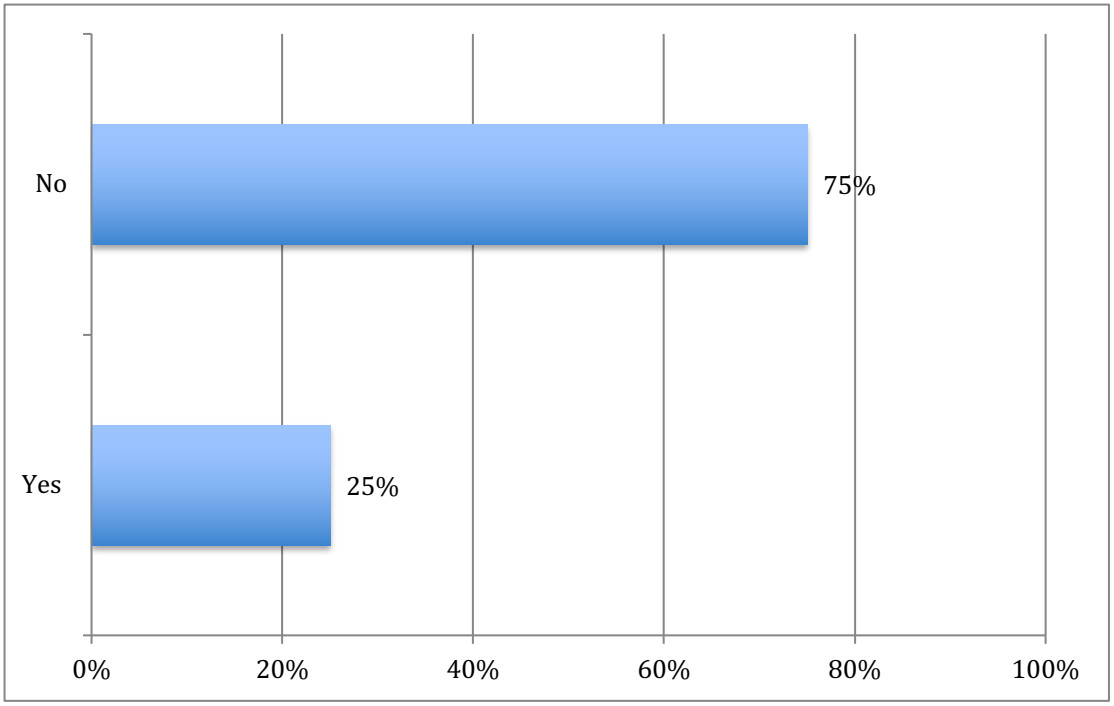


Figure 22. Would your management change if the patient were NHS exempt?

Questions	Summary of free text box answers
'Yes' to change in management if the patient were NHS exempt	Metal restoration UDAs

'No' to change in management if patient were NHS exempt	Tooth factors Patient equality

Table 15. Text box answers for change in management if the patient were NHS exempt

Summary from free text answers

Dentists felt that if the patient were exempt and non-paying then they would restore the tooth with a metal restoration whether that be a direct restoration e.g. amalgam or indirect restoration e.g. a metal cast restoration, tooth coloured restorations wouldn't be offered on the NHS and only privately.

The other reason for the dentist's management is they felt they could maximise their UDAs on exempt patients, as they would struggle to pay for the restoration if they were paying patients.

For the GDPs that said 'No', felt that their decisions wouldn't change based on patient exemption and the tooth should dictate the treatment. They felt paying and non-paying patients shouldn't be differentiated.

4.8.5 Results of vignette 3

Below is a summary of vignette 3 (see Appendix 5)

A 40-year-old fit and well male attends your practice with pain from the LR5.

You completed root canal treatment and symptoms resolved after one week. Intra-oral examination reveals a minimally restored dentition, low caries risk and good oral and periodontal health. The patient has a class 1

occlusion and no tooth surface loss. Radiographically the LR5 is well obturated to length with no voids or radiographic signs of a periapical area

4.8.5.1. Type of restoration for the LR5

The majority of GDPs preferred to restore the LR5 with an indirect restoration. The distribution can be seen in Figure 25.

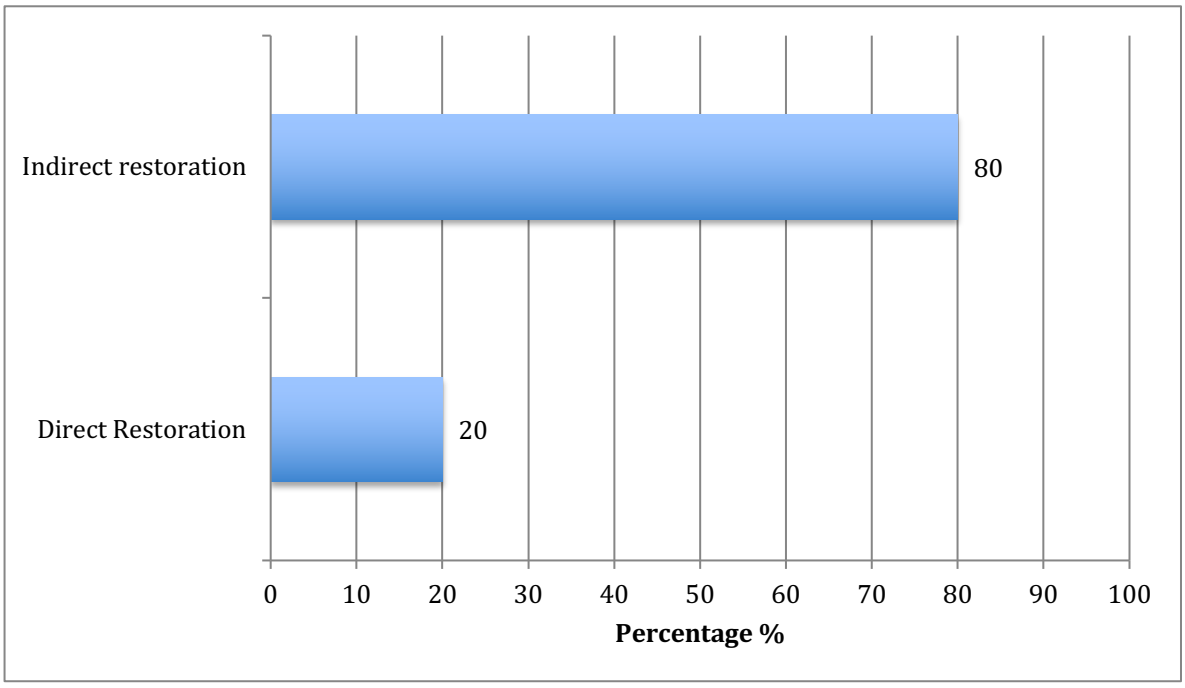


Figure 25. What is the most likely restoration for the LR5.

4.8.5.2 Change in management if the patient were a bruxist.

There were mixed and almost even feeling amongst the GDPs for their approach to change of management if the patient was a bruxist. Figure 26 shows the distribution in more detail. The common answers for the reasons for change in management can be seen in table 16.

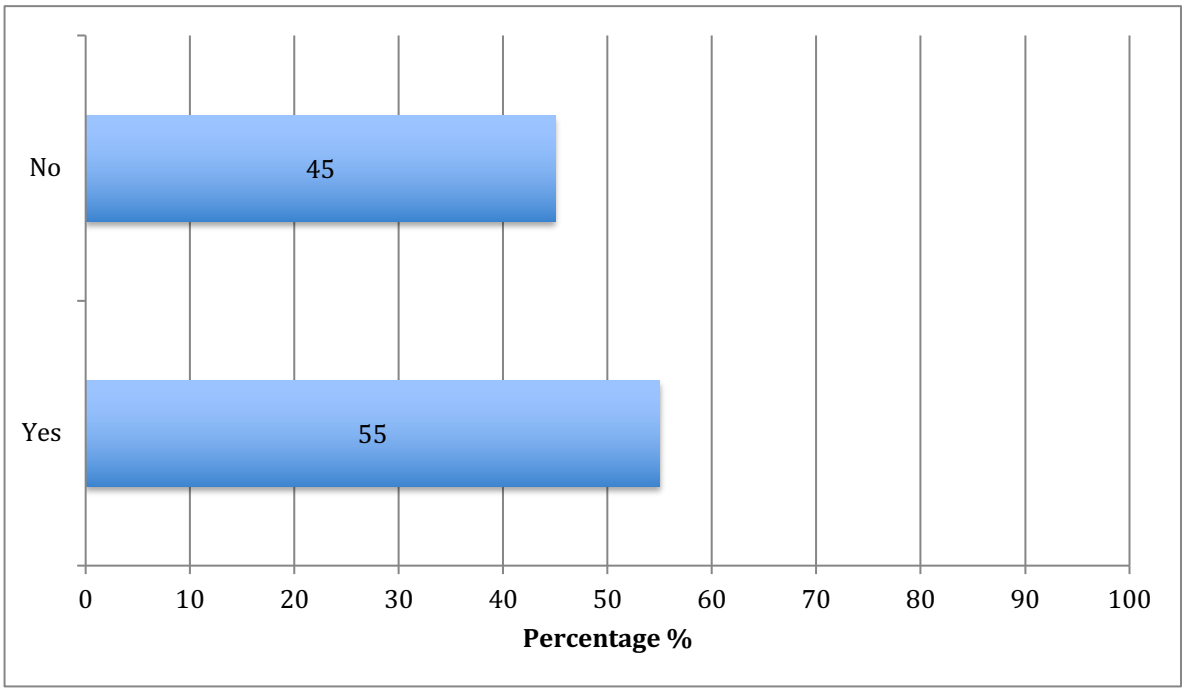


Figure 26. Would your management change if the patient were a bruxist?

Questions	Summary of free text box answers
'Yes' to change in management if the patient was a bruxist	Cuspal coverage

Table 16. Text box answers for change in management if the patient was a bruxist.

Summary from free text answers

Cuspal coverage was the main reason for changing management if patient was a bruxist. Fracture risk of the tooth was a concern and metal restoration were the preferred material to restore the tooth with. Although initially the majority of GDPs would restore the LR5 with an indirect restoration, those GDPs who answered 'direct restoration' were the GDPs that were noticed to have a mixed response to change of management of how to restore the LR5 if the patient was a bruxist. Those that would change their management preferred to restore the tooth with cuspal coverage rather than a direct restoration.

4.8.5.3 Choice of restoration if both marginal ridges of the LR5 were intact.

Two thirds of the GDP's would choose a direct restoration over an indirect restoration if both marginal ridges of the LR5 were intact. Figure 27 shows the distribution. The reasons for the GDP's choice of restoration is shown in Table 16.

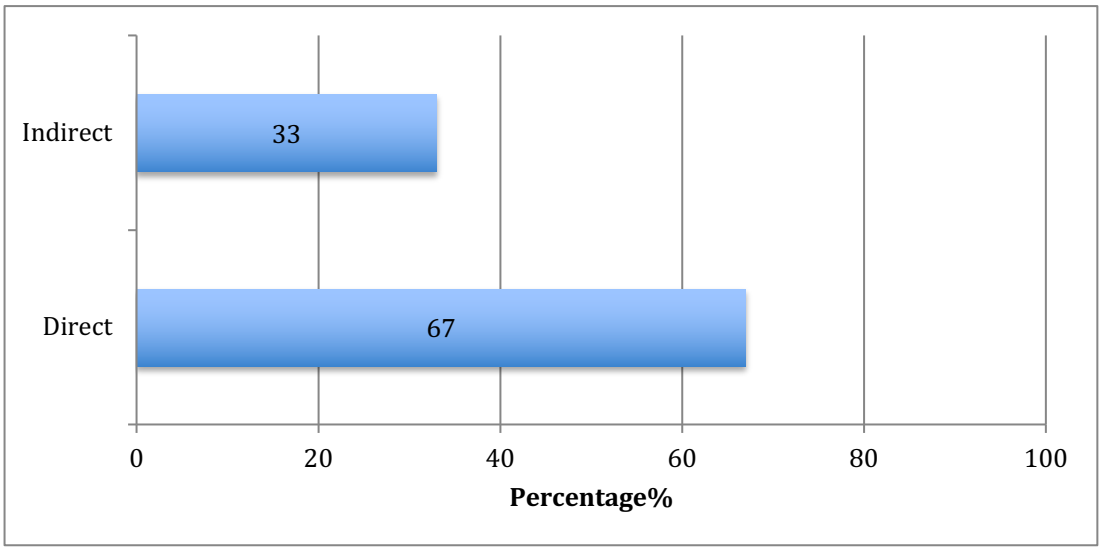


Figure 27. If both marginal ridges were intact for the LR5 what restoration would you restore the tooth with?

Questions	**Common text box answers based on a sample of 50 random surveys**
'Direct restoration'	Tooth structure Bonding
'Indirect restoration'	Cuspal coverage

Table 15. Text box answers for if both marginal ridges were intact for the LR5 what restoration would you restore the tooth with?

Summary from free text answers

Cuspal coverage was the main theme for GDPs that opted for an indirect restoration for the LR5 if marginal ridges were intact. Overall the feeling amongst these GDPs was that cuspal coverage was necessary for any root filled tooth regardless of the amount of tooth structure remaining.

4.9 Discussion

4.9.1 Discussion of general survey

The first section of the survey was general questions asked to the GDPs about their practice and confidence regarding restoring root filled posterior teeth. From the information gathered. It can be seen that a relative high percentage of GDPs qualified in UK (including England, Scotland, Wales and N. Ireland), this equates to around 83%.

When comparing these figures with the actual percentage of dentists registered in the UK with qualification from the UK this is around 85%. This is very representative of the GDP population. This information was obtained from the GDC freedom of information request (see Appendix 6). There was however variation with the number of years qualified which was found from this study's data and what is the actual number from the freedom of information from the GDC. This study's findings seemed to show a relatively even mix between 0-5 years, 6-10 years and 11-20 years of qualification, but a much smaller proportion of dentists in the 21-30 year and over 30 years qualified. The freedom of information shows an even numbers of dentists in all categories except in the 11-20-year group this can be shown in the table below.

No. of years since Primary Qualification was awarded	No. of Dentists
0-5 Years	7,747
6-10 Years	7117
11-20 Years	11,316
21-30 Years	7,721
30+	7,179
No awarding year recorded	16

Table 16. A breakdown of the number of years that dentists have been qualified for (taken form the GDC freedom of request April 2019)

The difference in discrepancy could be due to the fact that this survey was sent via an online link on social media and it is possible that the older qualified GDPs may not be users of social media and as a result less of these GDPs were captured. This will be discussed in more detail in strength and weaknesses of the survey section.

There seemed to be an even distribution of GDPs working in exclusively NHS, private and mixed practices. This information was not able to be obtained from the GDC freedom of information act or any other sources and is difficult to ascertain if the data captured by the survey is a true representation of the general population of GDPs. This was also true about the region of the UK the GDP works in. The data found a large proportion of GDPs that participated in the survey were practicing in the north of England. The reason for this is difficult to answer and there was no information available to refer to in order to get a true representation of the

population. It could be hypothesised that the dentists who are members of these closed dental social media groups maybe located mainly in the north of England.

Additional qualifications other than BDS were collected from the data. From the data it was found that approximately two thirds of the participants had some additional qualifications other than BDS. When comparing these figures with the freedom of information there was a discrepancy. The GDC declared that around 16% of dentists on the register that are not on the specialist lists hold additional dental qualifications, which are a non-primary qualification. The GDC describes a non-primary qualification as a qualification that does not enable registration on the GDC register. Non-primary qualifications were added to the register pre 2007, after this date non-primary qualifications were no longer added to registrant details on the GDC register. This could explain the difference between what this study actually found and what the GDC declared. The significance of this is that a large proportion of GDPs in the UK have additional training or have had some form of further assessment in addition to their basic qualification. This could impact on their ability to diagnose and treat more complex cases. However, it wasn't clear from the survey in which subjects the respondents had gained additional qualifications. What the data did find was a higher proportion of royal college of Edinburgh and England diplomas (MFDF, MJDF). These qualifications are general qualifications and not in any specific area such as Endodontology, or Prosthodontics. There were a small but similar percentages of GDPs with PG certificate, diploma and master's degrees. The subject areas of these qualifications were not

captured. There was a text box in the survey, which asked the GDPs to type in the subject they have obtained their additional qualification, however most dentists skipped this box. The software used Qualtrics has a feature, which doesn't allow the participant to move to the next question until they have answered the previous question. However, with this being a text box answer if any text or even a letter or character is put into the box, the software will allow the participant to go on to the next question without having captured any information at all. This seemed to have been a common occurrence with this question.

Confidence to restore root filled teeth was measured with the type of practice and the number of years qualified. The results showed a trend that the more qualified the GDP, the more confident they felt restoring root filled posterior teeth. This would seem logical, as the longer one is qualified the better their confidence becomes. This can be linked to more experienced GDPs as they would have had more exposure to a larger number of patients and therefore carried out more treatments. The more treatment one does the better they become at performing it, and hence this would improve their confidence.

Confidence with respects to the type of practice the GDP's worked in seemed to improve if the GDPs were working in private practice compared with NHS practice. This was however not statistically significant $P<0.001$.

The data showed more experienced GDPs tend to work more in private practice than less experienced GDPs. This would be logical when comparing confidence with NHS and Private practice. Confidence of GDPs

is higher in private practice than in NHS practice and this could be linked to the fact, the more experienced dentists work more in private practice and the more experienced one is the more confident they become. Previous research that looked into dentist's confidence and the impact on clinical practice. It was found that confidence was central to personal development and increased confidence helped tasks to be better completed (Fine *et al.*, 2019). If this finding is applied to the results of this study, it could be said more experienced dentists would have been more likely to have had more self-development and hence improved confidence.

Overall when the dentists were asked which type of restoration they restore root filled posterior teeth with, this was asked generally to get an idea of the overall consensus of what dentists like to restore root filled posterior teeth with, the majority of GDPs preferred to use an indirect restoration over a direct restoration. This would suggest an indirect restoration is more favoured generally. Previous research would agree with the majority of GDPs that preferred indirect restorations (Sorensen and Martinoff, 1984; Salehrabi and Rotstein, 2004). In these studies, root filled teeth survival was longer in those teeth that were crowned or had full coverage. However, as we have discovered from previous systematic reviews (Fedorowicz *et al.*, 2012a), and the one discussed in chapter 3, the evidence to suggest indirect restorations are more effective than direct restorations for root filled posterior teeth is weak and limited. Such decisions should be made based on many factors, which have been discussed in chapter 3 in the discussion section.

There was an even distribution of feeling between the GDPs when it came to whether or not they felt they had sufficient training as undergraduates to restore root filled posterior teeth.

The text box answers for ‘yes’ and ‘no’ showed that one main common answer that emerged for ‘yes’ to sufficient undergraduate training and two most common answers for ‘no’. Those GDPs that felt they had had sufficient undergraduate training felt that this was due to them having a lot of case to treat while being a student. Of these cases many crowns were done as well as root fillings. These GDPs were found to be of different experiences, there wasn’t any real reason that could be linked to why these GDPs answers from the 50-sample questionnaires felt they had enough experience at undergraduate level. It could only be hypothesised that at that particular time in their training they had more patients that required such treatments and as a result were able to perform more of these procedures. Requirements, which is the number of treatments one student needs to perform before they can exit dental school, was highlighted from the analysis. This may be important as the more times a dental student performs a certain procedure the better they will get at it, which is reflective of their answers being ‘yes’ to having sufficient training.

Limited number of root canal treatment performed, and limited teaching methods were common to the group that answered ‘no’. Previous research that looked into undergraduate confidence in their final year in the U.K showed that confidence for carrying out root canal treatment especially multi rooted root canal therapy was low around 28% (Gilmour *et al.*, 2016),

this was also seen in another study (Stewardson, Shortall and Lumley, 2003).

One reference was made to the tutors teaching the students. The understanding being, that the GDPs felt that the tutors only had experience in one aspect of the restoration of the root filled tooth. Previous research has suggested that trainers have expressed that they are only comfortable with performing root canal treatments of single rooted teeth and not multi-rooted teeth (Hayes *et al.*, 2001). Although the question asked was about the restoration of the multi rooted posterior root filled tooth, it wouldn't be unreasonable to suggest that if trainers are uncomfortable with doing the endodontics, their knowledge about how to restore these teeth could be a part of the overall lack of knowledge and experience treating these teeth from the initial endodontic procedure. However, fixed prosthodontics which would include restoration of root filled teeth have shown to have low confidence amongst undergraduate students (Youngson *et al.*, 2007).

The GDC guidance refers to the new graduate as a safe beginner looking to work as part of the dental team (Innes and Hurst, 2012). From this study it is clear that a large proportion of GDPs feel a lack of training at undergraduate level. More training and emphasis into such treatments, such as root canal treatment and restoration of the root filled tooth, needs to improve. Possible time constraints and increased number of undergraduate students maybe adding to the problem of 'not having enough patients to go around' and limiting the student's experience. Being comfortable and more importantly safe to perform endodontics and

subsequently restore the teeth comes with development of skill, which requires experience, only then the GDP will become more competent.

4.9.2 Discussion of vignette 1.

Scenario 1 has been described before in the results section and a copy of the survey is attached to the Appendix 4

The aim of the scenarios was to put various factors forward to the GDP and see what their answers would be based on the various factors.

The majority of the GDP's for scenario 1 preferred to restore the UR6 with an indirect restoration. Clinically the UR6 has lost a marginal ridge and has a large mesio-occlusal cavity. Based on the amount of tooth structure shown in the picture 70% of GDPs preferred an indirect restoration. Previous research has suggested that the loss of marginal ridges weakens the tooth (Mondelli *et al.*, 1980). A mesio-occlusal restoration can reduce the tooth's stiffness by as much as 63% (Reeh, Messer and Douglas, 1989). Choice of restoration for posterior teeth is determined mainly by the amount of remaining tooth structure. Root filled teeth that have lost marginal ridges generally are restored with cuspal coverage (Whitworth, Walls and Wassell, 2002). Although the systematic review in Chapter 3 concluded that there is not enough evidence for indirect restorations over direct restorations for the restoration of the root-filled posterior tooth, this was based on teeth having no posts. Previous reviews and research have been conflicting with some agreeing with the conclusions of the systematic review in Chapter 3 (Fedorowicz *et al.*, 2015) and another review concluded that the survival of crowned teeth, which is an indirect

restoration to be more than that of an direct restoration (Stavropoulou and Koidis, 2007). Having these conflicting results, it is therefore reasonable for the majority of GDPs to have chosen an indirect restoration as the evidence isn't clear for either type of restoration. It must be noted that previous reviews included teeth with posts, also the extent of remaining tooth structure is not clear from the studies and therefore difficult to compare with the tooth in scenario 1. One of the studies that was included in the systematic review in Chapter 3 looked at amalgam restorations which had lost marginal ridges in root filled premolars and molars (Hansen and Asmussen, 1990). The authors concluded a low survival for these direct amalgam restorations. However, when we analyse this study this was a retrospective study and difficult to know how or who selected the teeth for inclusion in the study. It also wasn't clear on the volume of tooth remaining which is important when considering the final restoration. In this study there was no comparison group i.e. no indirect restoration to compare with, as well as no other similar study with similar trial characteristic to compare with. Therefore there isn't enough information to suggest that a direct restoration is better than an indirect restoration for a root filled posterior tooth that has lost marginal ridges, When this was extrapolated to see if there was a similar trend when comparing GDP's experience in years with the choice of restoration for the UR6, the trend seemed to be the same, in all categories except the 0-5 years qualified more GDPs seems to prefer indirect restoration over a direct restoration. It is the author's opinion that the reason why an indirect restoration was the majority choice of restoration is because of the ease of placement over a direct restoration,

and the improved mechanical integrity an indirect restoration possesses over a direct restoration.

When type of practice was compared with the choice of restoration the results showed that similar percentage of GDPs chose indirect restoration for both NHS and Private practice. The results for this question would suggest that the overall majority decision to restore the UR6 was based on the amount of tooth structure remaining and followed the pattern of what has been mentioned in previous literature.

The next factor that was investigated for scenario 1 was patient symptoms and how this would change the management. The majority (85%) of the GDPs felt that their management regarding the restoration for the UR6 would change if the patient has persistent symptoms after the root canal treatment.

Referral of the patient to a specialist was a common theme amongst the GDPs and the rationale behind this was to reduce risk of complaints and litigation from the patient, and particularly in this scenario the root filling was done to a good standard, the GDPs felt if symptoms continued they couldn't improve on this and preferred to refer to a senior colleague such as a specialist.

Litigation and complaints have now become common in general dental practice. These can range from contractual disputes to patient complaints (Beynon, 2015). The fear of this can be very stressful for the GDP. Dental practice differs from many other health professions, with practitioners undertaking multiple high-risk surgical procedures on a daily basis. These

characteristics may place dental practitioners at an increased risk of certain forms of legal and regulatory action compared with practitioners from other health professions (Thomas *et al.*, 2018). With root canal treatment being a complex procedure and when it doesn't go to plan or the patient hasn't benefited from the treatment a referral maybe considered which will take the stress off the GDP by sending the patient to a colleague. As most complaints and litigation cases in dentistry are related to treatment (Thomas et al., 2018), to reduce the risk to the GDP and avoid escalation of a complaint, it wouldn't be unreasonable and completely understandable why a referral may be considered.

GDPs felt that the symptoms could be unrelated to the root canal treatment and therefore considered referral not because of litigation or complaints but because they felt that there could be another underlying cause for example non-odontogenic pain. A systematic review found that non-odontogenic pain is not an uncommon outcome following root canal therapy and may represent half of all cases of persistent tooth pain (Nixdorf *et al.*, 2011). Given this finding and if the source of pain cannot be determined then referral is justified. However, the other side of the argument is that after root canal treatment prevalence of post-operative pain is well known (Nixdorf *et al.*, 2010). It is also understandable for practitioners to wait till symptoms have subsided before providing further treatment. However previous research has evaluated the relationship between the quality of the coronal restoration and the quality of the root canal filling by examining the radiographs of endodontically treated teeth (Ray and Trope, 1995). They observed that a combination of good restorations and good endodontic

treatments resulted in absence of periapical inflammation in 91.4% of the teeth, whereas poor restorations and poor endodontic treatments resulted in the absence of periradicular inflammation in only 18.1% of the teeth examined. Furthermore, where poor endodontic treatments were followed by good permanent restorations, that appeared radiographically sealed, the resultant success rate was 67.6%. They concluded that apical periodontal health depended significantly more on the coronal restoration than on the technical quality of the endodontic treatment (Ray and Trope, 1995). This was a retrospective study, looking back at over a thousand endodontically treated teeth. The study didn't make clear which population the participants belonged too, i.e., was it a university setting or general practice? There was no information on how the teeth were selected for inclusion in the study, the outcome measures were based on examining periapical lesions, a two-dimension method using periapical radiographs, they had no information of the quality of the radiographs included. The coronal restoration was also assessed radiographically, which asks the question, how reliable is coronal assessment on a radiograph, would clinical examination of the restoration for quality have been more appropriate. This can make decision making for the GDP difficult when deciding when to proceed with treatment especially as the patient still has symptoms. Do they wait, or do they proceed with treatment? The evidence would suggest that delaying the definitive restoration can allow more leakage of bacteria back into the root canal system, this is because a temporary restoration is less well sealed and allows the penetration of more bacteria (Uranga *et al.*, 1999). This study is an in vitro study and whether

or not the results of this study can be applied to general practice is questionable. The added problem of proceeding with treatment in the presence of symptoms is that GDPs could be at risk of a complaint, which was one of the reasons indicated in this study for the change in management. There is evidence, although weak evidence to suggest that a good coronal restoration has an impact on the success of the root filled tooth, however, decisions should be made based on the patient's needs and case by case.

Those GDPs who persistence symptoms wouldn't change their management preferred to restore the tooth to have a good coronal seal, this is sensible and the importance of good coronal seal has been well researched in the past (Ray and Trope, 1995). It can be assumed that this group of GDPs are less worried about litigation and complaints and prefer to complete treatment and subsequently review the symptoms. Using composite as a material in a situation where symptoms are still present was an interesting finding. Composite as a material is widely used in dentistry and has many advantages as discussed in Chapter 2. Should a root filled tooth that is restored with composite and needs to be retreated, composite is a much more easier material to cut through back into the pulp chamber as opposed to metal or porcelain (*Principles and Practice of Esthetic Dentistry*, 2016). This would make the GDP more confident of re-entering the tooth should there be more problems but at the same time be happy that the tooth has been well sealed.

The next factor looked at caries risk for scenario 1 and how this would change the management. There was a 100% agreement between dentists

that if the patient were high caries risk this would have an impact on their treatment, and this would be to defer the definitive restoration. Patients with high rate of caries are likely to develop more caries and therefore is it advised that more complex treatment such as indirect restorations should be deferred until the caries rate has reduced and no new carious lesions are present (SDCEP, 2012). This is good practice and it was pleasing to see that this factor was important to the participating GDPs.

For those that said that their management wouldn't change if caries risk of the patient was high felt that placing the definitive indirect restoration would not have any impact. This could be because the GDPs felt that if the root canal treatment has been started then the whole treatment for that tooth should be completed and reference can be made to previous research to support the argument that coronal restoration is as important as a good root canal treatment in reducing apical periodontitis (Ray and Trope, 1995). Other reasons could be if they left the tooth incomplete then the GDPs could be more at risk of a complaint from the patient or their interim/temporary restoration could leak which could make the treatment fail.

The next factor that was looked at was the paying status of the patient with relation to a change in management.

For those that said 'no' to change in management if the patient was exempt from paying for treatment it was thought that they didn't see a difference between paying and non-paying patients. The feeling of equality between the two paying statuses of patients was clear. There is no mention in the

literature of how dentists treat paying and non-paying NHS patients, however from this research it was found that paying status does have some impact on the GDPs decision making when restoring the UR6. GDPs felt that if patients don't pay for treatment, they can offer the higher banding of treatment, which the paying patient would need to pay for but would become free for the non-paying patient. The view some GDPs took was that they were helping the patient by offering the higher band of treatment. If their paying status changed and became a paying patient, they may not be able to afford such treatment and therefore offering them that treatment while they are exempt is appropriate. This sounds reasonable but there could be a case where the GDPs could be over treating, this would depend on a case by case basis, however when looking at the case in scenario 1, this tooth has lost a marginal ridge and it wouldn't be deemed as over treatment if it were to be restored with an indirect restoration (Tait, Ricketts and Higgins, 2005).

This research showed that metal restorations especially indirect metal restorations were much preferred in the exempt non-paying NHS patient to restore the UR6. The rationale behind this could be because metal restoration tends to be cheaper to make in the laboratory than tooth coloured restorations. Previous research conducted has showed that dentists tend to choose less aesthetic options for molar teeth when compared with premolar teeth (Baechle, 2015). This was also seen to be the case from this research. Molar teeth are further back placed in the mouth and are less visible when smiling than premolar teeth. Coupled with the saving in laboratory cost compared with tooth coloured restoration and

the position of the tooth in the arch metal restoration seemed to be a common choice for the exempt patient. From the NHS guidelines in April 2019 (*What is included in each NHS dental band charge?*, 2019), it details what treatments are available in each banding. Indirect restorations fall into band 3, however, it is not clear that tooth coloured indirect restorations aren't available as a band 3 treatment. There is reference to 'other 'cosmetic treatments not available on the NHS. This seems to be a little confusing and could be open to interpretation. Some GDPs may classify tooth coloured restorations on posterior teeth as 'other' cosmetic treatment and others may not. This is interesting as not all GDPs place metal indirect restorations on posterior root filled teeth.

The GDPs felt that with non-paying exempt patients UDAs targets could be maximised by treating them with the highest band, which is the dental currency that dentists in England and Wales operate within the NHS and get paid by. Targets are usually set by the NHS to the dentist or the practice the dentist works in to achieve a certain number of UDAs per annum (Burke, 2017). The other important thing to note about the UDA system is that the GDPs felt that with exempt patients they could claim two courses of treatment, one for the root canal treatment and one for the indirect restoration, which would be done after a period of three months. The reason for the three-month gap between treatments is that the GDP is allowed to open up a new course of treatment after three months (Jones, 2018). This way the GDP will be able to claim two courses of treatment for the same tooth compared to one, increasing their profit. This is most likely

related to the GDP's expressed unhappiness with the NHS system and lack of remuneration (Jones, 2018).

GDPs were more similar in their thoughts when asked if their management would change if they wanted a private option.

For those GDPs that said 'yes' they felt that they were able to offer more options, choices of materials to their patients. With private options there are no restrictions or ambiguity for the dentist when offering options. All options are available to the patient and the dentist and decisions are mostly based on cost and what the patient wanted. The GDPs also preferred increased profits with private options as they can charge more and have the freedom of laboratory use as the patient covers the costs. Most dentists work in mixed practices where both NHS and private treatment can be mixed, however, although this can be beneficial to the dentist there can be a perception to the patient that private patients are more prioritised and less rushed (Steele, 2009).

The GDPs that said 'no' to change in management if the patient requested a private option, felt there was no difference between NHS and private dentistry. They felt that all options could be offered on the NHS. Reason for this could be firstly be down to the unclear NHS guidelines discussed previously ('NHS choices. (n.d.). Consent to treatment. Retrieved from http://www.nhs.uk/Conditions/Conset-to-treatment/Pages/Introduction.aspx', no date).

4.9.3 Discussion of vignette 2.

Scenario 2 has been described before in the results section and a copy of the survey is attached to the Appendix 4.

First question in scenario 2 discusses how long the GDPs will wait to place the definitive restoration on the LR6 based on the practice the GDP works in. The results show that there is variation between the GDPs when it comes to the timing of the definitive restoration. There doesn't seem to be a particular trend for NHS and Private dentists. The majority of the dentists, around 34%, would prefer to restore the LR6 immediately after obturation of the tooth.

Various reasons in the scenario could have influenced their decision, such as the LR6 was not ideally obturated to length in the distal root, it was 3mm short. According to European Association of Endodontists, a satisfactory root canal treatment shows a tapered canal from crown to apex and completely filled with no space between canal filling and canal wall. In addition, it should be 0–2 mm short of the radiographic apex to prevent post treatment failure (Löst, 2006). A previous systematic review has shown root fillings that extend less than 2mm from the radiographic apex, have a higher chance of failure (Ng *et al.*, 2008). The variation in the answers could be explained by linking the reduced success rate to uncertainty of endodontic success based on the findings of the systematic review. Some dentists may want to delay the restoration till they can be sure that there are no symptoms or signs of no radiographic changes. They

may even consider retreating or even referring to a specialist before commencing with a definitive restoration.

Both NHS and private dentists chose indirect restoration over direct restoration to restore the LR6, and in equal proportions between the two sectors. This was an interesting finding. The tooth in this scenario has an occlusal cavity. An occlusal cavity preparation reduces tooth stiffness by 14 to 44 % and a mesio-occluso-distal (MOD) one by 20 to 63 % (Larson TD, Douglas WH, 1981). Endodontic procedures only decrease tooth stiffness by 5%, which is associated with access opening. Restorative procedures reduce tooth stiffness by a lot more (Larson TD, Douglas WH, 1981). Bearing this in mind, the GDPs opted for a more destructive restoration such as an indirect restoration for a tooth with a relatively small access cavity. Preparation of the LR6 for a crown for example would further reduce the tooth's stiffness. However, the GDP's majority choice could be justified. The patient is scenario 2 has an anterior open bite (AOB), meaning only opposing posterior teeth contact when the patient is biting down. Posterior teeth in patients with AOB tend to be more worn and have fractures of their cusps (K. *et al.*, 2018). To avoid this from occurring the GDPs could have opted for cuspal coverage indirect restoration and could explain the higher indirect restoration percentage.

The other interesting point to note is that when the GDPs were asked if they would change their management if the patient had a class 1 occlusion, where the front teeth and back teeth touch, 70% of the GDPs wouldn't change their management and would still place an indirect restoration. The GDPs felt that, if the tooth was to be restored with a direct restoration then

this could be done with amalgam or composite. Those that favoured amalgam did so for the reason that amalgam is a functional restoration for an occlusal cavity and if the patient wanted a tooth coloured then they would have to pay privately. Some GDPs didn't share the same feeling and would place a direct composite restoration, these GDPs could be working in private practice or possibly in the Scottish NHS system where dentists aren't paid for posterior composite restorations. Those that opted for indirect restorations mainly were concerned about cuspal coverage and to prevent the tooth from fracture. There wasn't much information on the type of indirect restoration they would restore the LR6 with from the collected answers, except for using a metal indirect restoration to restore the LR6. This was justified by GDPs as being a non-cosmetic tooth and that metal restoration would be appropriate. UDAs were another important factor to the GDPs when it comes to non-paying NHS patients. They felt that to increase their profit they would need to restore the LR6 with an indirect restoration. This would increase the number of UDAs they would achieve from that course of treatment, which meant more pay. They also felt that non-paying patients would benefit from getting the higher cost treatment as if it's no charge to the patient then it would better for them to receive it while they are having the same course of treatment, rather than during a future course of treatment when they would have to pay for that treatment. Similar to scenario 1, GDPs who didn't feel payment was an issue, did not because of tooth factors being the driver for treatment decisions and that all paying and non-paying patients should get the same options and treatment.

4.9.4 Discussion of vignette 3.

Scenario 3 has been described before in the results section and a copy of the survey is attached to the Appendix 4.

The first question in scenario 3 refers to the most likely restoration the GDPs would place to restore the root filled LR5. The results would show that an indirect restoration was the favoured option by 80 % of the GDPs. The LR5 has lost two marginal ridges and the lingual wall. This is a lot of tooth structure and as a result the stiffness of the tooth would be reduced by around 63% (Larson TD, Douglas WH, 1981). It would be challenging to restore this tooth with a direct restoration, coupled with the reduction in stiffness it is logical that an indirect option be chosen to restore this tooth and has been supported by previous research (Whitworth, Walls and Wassell, 2002).

There was a text box to ask the GDPs their reason for their choice. From the analysis of the raw data it was apparent that this box wasn't filled out or skipped and therefore reasoning for their choice wasn't found. It could be speculated that the reasons would have been very similar to the answers in the previous scenarios, which mention the amount of tooth structure lost and the need for cuspal coverage when marginal ridges have been lost.

The GDPs were quite even in their thoughts when it came to their management if the patient in scenario 3 was a bruxist. Bruxist patients often have tooth wear. Tooth wear is a multifactorial disease. Worn teeth

have been traditionally restored with direct composite, however composite is a challenging material to work with, it can shrink and fail repeatedly, and for these reasons indirect restorations such as crowns could be considered (Loomans *et al.*, 2017). The controversy with crowns as mentioned in chapter 2 are that they require more tooth removal and when the tooth has already lost tooth structure from tooth wear this makes decision making difficult (Varma, Preiskel and Bartlett, 2018). This could explain the difference in opinion of the GDPs.

For those GDPs that said 'Yes' to change in management if patient was a bruxist, the reasons were to restore the tooth with cuspal coverage. This was the main emerging response. The feeling from the GDPs were that teeth that have tooth wear have a higher risk of fracture especially if they have been root treated due to the increase force applied on chewing motions. Metal restoration was another common factor, they felt that porcelain would increase the rate of tooth wear and a metal cuspal coverage restoration would be a better choice.

Two thirds of the GDPs opted to restore the LR5 with a direct restoration over an indirect restoration if the LR5 had both marginal ridges intact. Having both marginal ridges intact would mean that the tooth would have an occlusal cavity. As previously mentioned, a tooth with an occlusal cavity reduces the stiffness between 14-44% and an endodontic access cavity reduced the stiffness by a further 5%. This is a lot less than if marginal ridges were lost. A direct restoration is more conservative than an indirect restoration and from the text box analysis for those GDPs that chose direct restoration the reasons were amount of remaining tooth structure,

signifying the limited tooth loss for an occlusal cavity. The other reason was bonding. What this means is that there is more tooth for a direct restoration to bond to in an occlusal cavity and this improves the retention of the restoration. A third of the GDPs that chose an indirect restoration the one and only common answer was ‘cuspal coverage’. The reasons described from the direct quotes mentioned that they felt cuspal coverage was necessary for any root filled tooth, cuspal coverage needed to reduce fracture.

The GDPs for this scenario felt that the LR5 should be restored after the resolution of signs and symptoms. 87% of the GDPs chose this answer. The patient had pain after the root canal treatment. This is the most likely reason for the delay in restoring the LR5. GDPs have previously expressed fear of complaints and litigation with regards to continuing treatment from patients especially when they still have symptoms. Also restoring the tooth while there are symptoms can make re-treating the tooth more challenging.

4.9.5 Strengths and limitations of the study

4.9.5.1 Survey design

This study used an online link electronic survey methodology, which is worth some reflection. For this study this method was highly effective in collecting data. This method was able to capture many GDPs as the professional forums where the link was displayed have many active members. The link could also be passed on from one participant to the other on their social media profile and the people following them who would

be eligible to participate could be informed and hence increase participation rates.

A major problem with the use of online surveys is ensuring that an up-to-date and accurate email address list is available for potential participants. Email addresses for institutions and individuals change for many reasons and contact lists are sometimes accurate only for short periods of time. This could have explained the low response rate this study got from emails. A further disadvantage is that many people have more than one email address and may rarely check other accounts. Additionally, individuals move jobs and institutions, this may affect whether a respondent can appropriately participate in a survey. A recent survey showed that almost 10% of emails sent using an one-year-old contact list were returned as undeliverable. (McPeake, Bateson and O'Neill, 2013). Other issues being errors in participants entering data as well as online/electronic surveys are restricted to those participants who have access to a computer or electronic devices (Electronic, 2014). These limitations could be seen in this study. The main age demographics were between 0-20 years qualified. Older qualified dentists over 20 years made up less than a quarter of the participants. These dentists may have limited access to computers and electronic devices and be less familiar with social media and subsequent professional groups.

To improve the exposure to the GDPs that were over 20 years qualified, a postal survey may be been a better method. Self-administered questionnaire only requires questionnaire distribution, doesn't need training, for example on the software. This mode is less susceptible to

information bias and interviewer effect but have greater chance of having no response items. The main advantages of self-administered questionnaires is that it can reach a large sample size, cover wide geographical area, cover population which is sometimes difficult to reach, excellent for capturing sensitive topics and more cost effective compared to other modes of administration.

Another issue, which was seen, using this online method of survey distribution, is that these professional forums generally have dentists with similar interests and possibly similar philosophies. This can't be said for every participant and is more of an observation found from the results and answers to many of the questions to this survey. This could create bias in the results, as the study may have only captured a narrow portion of the GDP population that have a similar mind-set.

Overall the electronic survey method was found for this study to be an effective way to gain as many responses as possible to be able to conduct this research.

4.9.5.2 Survey Distribution

The number of dentists to target was 400. This study managed to get over 500 responses back and this was achieved within 6 weeks of distributing the link on social media. The reason for this could be the timing of survey distribution. The link went live over the Christmas break. With the link being on social media many people would have been off work during this period and may have had more time and access to social media platforms and as a result been able to take part in the survey.

4.9.5.3 Target population

The number of GDPs in the U.K. is around 40,000. In this study the number of responses were around 500. This equates to 1.3% of the general dentist population. The social media forums where the link was posted and most of the responses came from have around 15,0000 subscribers. This is around 3% of the social media forum population. How representative this population is compared to the GDP population is impossible to know this is a potential flaw in this study.

4.9.5.4 Ethical approval

There were some issues with ethical approval and took some four months to obtain. The ethics form was returned with comments to be amended. The comments related to GDPR (General Data Protection Regulation). This was implemented just around the same time as when the ethical approval was applied, and this had previously not been anticipated. The main concerns were with questions about the email addresses we were obtaining. They queried if the emails of the dentist available on the database had opted in to receive emails. After consultation with the database company (UK database) used to obtain the email addresses. The company reassured us that all their stored emails were GDPR compliant. The GDPR advisor at the University of Liverpool was contacted for advice. The opinion was made, that if the companies were GDPR compliant then it would be appropriate to obtain the email addresses. In addition to this the ethics committee also wanted clarification of consent of participants

who were answering this survey on social media. This was overcome by having an accompanying letter with the link attached and consent would be obtained from the participant only if they opened the link.

4.9.5.5 Case vignettes

In this study the case vignettes were accompanied with pictures of teeth and questions related to the clinical scenario. The aim of this was to investigate the GDP's thoughts on how they would restore the tooth in the picture based on the information given (which included various factors). It is impossible to directly observe hundreds of dentists in front of the same patient or tooth to make their decision, so this method was used for its' ease of delivery, quickness and being cost effective with the GDP not having to leave their work place (Veloski *et al.*, 2005).

The downsides to vignettes according to Hughes et al (Hughes, 1998) are that they may not always be able to capture interactions or reflect reality in the way that physicians communicate with their patients. This was found to be true in this study.

4.9.5.6 Summary of discussion

This study revealed that decision-making for the restoration of the root filled posterior tooth can be influenced by many factors. Some of these are tooth related, for example the amount to remaining tooth structure. Other factors include, the paying status of the patient. Symptoms of the patient post root canal treatment and caries status was also found to influence treatment decisions. In the author's opinion the overall feeling amongst NHS GDPs was that root canal treatment is poorly paid in the health service and this

has an influence on the overall treatment of the root filled tooth in order to maximise the payment. There is also confusion when it comes to restoring root filled posterior teeth, this study has been shown that there has been various teaching methods taught at undergraduate level and as a result GDPs are doing different treatment modalities and have different perceptions regarding restoration of the root filled posterior tooth as well as mixed feelings regarding the adequacy of their undergraduate training. GDPs that work in the private sector seemed to be more confident in their approach to restoring root filled posterior teeth. However, private GDPs tended to be older than NHS GDPs and more experienced. The freedom to being able to charge patients outside the NHS gave GDPs more choices to offer to the patient and increased subsequently increase their profit margins.

4.9.6 Conclusion

- **Undergraduate training**- GDPs have mixed opinion about their undergraduate training when it comes to restoring root filled posterior teeth. The main reasons to improve this is more exposure to endodontic treatment and being taught more up to date techniques
- **Practice**- GDPs in NHS practices are less confident when providing restorations for root filled teeth compared with private dentists. Private dentists are generally more experienced dentists compared with NHS and the increase in experience may account for the increased confidence.

- **Financial-** There is evidence from this study to suggest that finances can drive treatment decisions. Although for the majority of GDPs, finances wouldn't change their management, however, for some GDPs felt that on exempt patients UDAs can be maximised.
- **Patient factors-** High caries risk and persistent symptoms were important factors to the majority of the GDPs and influenced decision-making.
- **Tooth factors-** Remaining tooth structure was the main factor with respect to restoring root filled posterior teeth for the GDP.
- **Timing of restoration-** There was no real pattern found amongst the GDPs from this study.

Overall what this study has highlighted that GDPs vary in their approach. Experience in terms of year's qualified and undergraduate experience is paramount to the GDPs confidence and decision-making. It may be important to consider this when designing future undergraduate programs and emphasis be placed on providing students with more exposure with restoring root filled teeth. More postgraduate training focused to GDPs may also be needed.

The treatment to recommend to which patient remains a decision that must be made on a case-by-case, tooth-by-tooth, and patient-by-patient basis.

Chapter 5

5.1 Overall conclusions and suggestions for future research

The systematic review highlighted that there is limited evidence of poor quality to assess the effectiveness of a direct restoration over an indirect restoration for restoring root filled posterior teeth without posts. More emphasis should be made in conducting robust randomised controlled trials with attempts to limit bias in order to be able to answer the research question. Although in theory this is possible, the reality is somewhat different. As discussed previously in this thesis, there are many factors that can affect the outcome of restorations on root filled teeth. No two teeth or patients are the same, which can make getting similar groups of participants difficult. Future research could focus on the relative effects of tooth structure loss when restoring root-filled posterior teeth. The occlusal scheme the tooth is in as well as the participants risk of caries could be factors that can be investigated. Patient expectations of treatment and cost analysis of the two interventions could also be researched from both a dentist and patient perspective.

Due to the lack of evidence from the systematic review, the formation of the second study, the survey to GDPs was created. The thinking behind this was, if the evidence to restore a root filled posterior tooth is limited and poor, why, and how are GDPs making their decisions when deciding how to restore the root filled tooth. What influences their decisions?

The survey identified that decision making for restoring root-filled posterior teeth was affected by many different factors for the GDPs. The most common factors were, undergraduate training, financial implications, patient factors and tooth factors.

This study used an online survey method to get GDPs answers. Future research should consider using interviews to get qualitative results, which could capture more open responses about the issues the GDPs, may or may not be having. It also must be remembered in a face-to-face interview, the participant maybe less willing to tell the truth by feeling under pressure.

The methodology of this study could be repeated. Changes for future research could include possibly getting the patient's perspective on their thoughts and perceptions on restoring their root filled tooth. This study has highlighted that patient factors and financial implications are important to decision making. How these decisions affect the patient personally could be investigated. This could change the shift to more patient focused treatments.

Appendices

Appendix 1. Search history

mSearch history

Databases	Date searched	No. retrieved
MEDLINE (Ovid), Epub ahead of print and MEDLINE In-Process (Ovid)	21/12/2019	3464
EMBASE (Ovid)	21/12/2019	7842
CDSR	21/12/2019	5
CENTRAL	21/12/2019	1888
DARE	21/12/2019	11
Web of science	21/12/2019	1543

Search strategies

Database: CDSR/Central/ DARE/HTA		
#1	MeSH descriptor: [Endodontics] explode all trees	1333
#2	MeSH descriptor: [Root Canal Therapy] explode all trees	1056
#3	MeSH descriptor: [Tooth, Nonvital] explode all trees	174
#4	((Endodontic or "root canal") near/3 (treat* or therap*))	1177
#5	((nonvital* or non-vital* or devital* or pulpless) near/3 (tooth or teeth))	216
#6	#1 or #2 or #3 or #4 or #5	1812
#7	MeSH descriptor: [Dental Amalgam] explode all trees	305
#8	MeSH descriptor: [Composite Resins] explode all trees	1908
#9	MeSH descriptor: [Resin Cements] explode all trees	1389
#10	MeSH descriptor: [Glass Ionomer Cements] explode all trees	703
#11	MeSH descriptor: [Dental Restoration, Permanent] explode all trees	1452
#12	(Amalgam* or Composite* or Resin* or "Glass ionomer")	18787
#13	((direct* or permanent* or dental*) near/3 restor*)	2956
#14	MeSH descriptor: [Crowns] explode all trees	751

#15	MeSH descriptor: [Post and Core Technique] explode all trees254
#16	MeSH descriptor: [Inlays] explode all trees 143
#17	(Crown* or Onlay* or Inlay* or Endocrown* or (indirect* near/1 restor*)) 2172
#18	"post and core technique*" 257
#19	MeSH descriptor: [Dental Restoration Failure] explode all trees 1084
#20	#7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 21240
#21	#8 and #20 1908

Database: Medline

Strategy used:

1	endodontics/ or "root canal therapy"/	14092
2	((Endodontic* or "root canal") adj3 (treat* or therap*)).tw.	11010
3	Tooth, Nonvital/	1845
4	((nonvital* or non-vital* or devital* or pulpless) adj3 (tooth or teeth)).tw.	1066
5	1 or 2 or 3 or 4	21190
6	Dental Amalgam/	8760
7	composite resins/ or resin cements/	27418
8	Glass Ionomer Cements/	6621
9	Dental Restoration, Permanent/	20339
10	(Amalgam* or Composite* or Resin* or "Glass ionomer").tw.	192020
11	((direct* or permanent* or dental) adj3 restor*).tw.	6763
12	crowns/ or "post and core technique"/	17695
13	Inlays/	3269

14	(Crown* or Onlay* or Inlay* or Endocrown* or (indirect* adj1 restor*)).tw.	40491
15	"post and core technique*".tw.	26
16	Dental Restoration Failure/	7285
17	or/6-16	253592
18	5 and 17	5485
19	Animals/ not Humans/	4770723
20	18 not 19	5284
21	limit 20 to english language	4677
22	remove duplicates from 21	4527
23	case studies/ or case reports/ or editorial/ or news/ or opinion/	2695756
24	exp In Vitro Techniques/	611945
25	23 or 24	3302848
26	22 not 25	3464

Database: Embase

Strategy used:

1	endodontics/ or "root canal therapy"/	27269
2	((Endodontic* or "root canal") adj3 (treat* or therap*)).tw.	9353
3	Tooth, Nonvital/	4893
4	((nonvital* or non-vital* or devital* or pulpless) adj3 (tooth or teeth)).tw.	900
5	1 or 2 or 3 or 4	32825

6	exp Amalgam/	1966
7	composite resins/ or resin cements/	38922
8	Glass Ionomer Cements/	6104
9	exp Dental Restoration/	56374
10	(Amalgam* or Composite* or Resin* or "Glass ionomer").tw.	206174
11	((direct* or permanent* or dental) adj3 restor*).tw.	6241
12	crowns/ or "post and core technique"/	20124
13	exp Inlay/	326
14	(Crown* or Onlay* or Inlay* or Endocrown* or (indirect* adj1 restor*)).tw.	47567
15	"post and core technique*".tw.	22
16	Dental Restoration Failure/	1448
17	or/6-16	301293
18	5 and 17	9952
19	Animals/ not Humans/	1305140
20	18 not 19	9451
21	limit 20 to english language	8370
22	case studies/ or case reports/ or editorial/ or news/ or opinion/	614543
23	exp In Vitro Techniques/	4872629
24	22 or 23	5475356
25	21 not 24	7842

Database: Web of Science

# 1	6,151	TS=((Endodontic or "root canal") NEAR/3 (treat* or therap*))	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 2	689	TS=((nonvital* or non-vital* or devital* or pulpless) NEAR/3 (tooth or teeth))	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 3	6,689	#2 OR #1	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 4	856,139	TS=(Amalgam* or Composite* or Resin* or "Glass ionomer")	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 5	7,116	TS=((direct* or permanent* or dental*) NEAR/3 restor*)	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 6	132,008	TS=(Crown* or Onlay* or Inlay* or Endocrown* or (indirect* NEAR/1 restor*))	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 7	83	TS=("post and core technique*")	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 8	2,557	TS=(Dental* Restorat* Fail*)	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 9	983,893	#8 OR #7 OR #6 OR #5 OR #4	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*
# 10	1,543	#9 AND #3	*Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years*

Appendix 2. USPHS criteria

Modified United States Public Health Service (USPHS) Ryge Criteria for Direct Clinical Evaluation of Restoration

COLOR MATCH

Alpha (A) *Visual inspection*
The restoration appears to match the shade and translucency of adjacent tooth tissues.

Bravo (B) *Visual inspection*
The restoration does not match the shade and translucency of adjacent tooth tissues, but the mismatch is within the normal range of tooth shades. (Within normal range: Similar to silicate cement restorations for which the dentist did not quite succeed in matching tooth color by his choice among available silicate cement shades.)

Charlie (C) *Visual inspection*
The restoration does not match the shade and translucency of the adjacent tooth structure, and the mismatch is outside the normal range of tooth shades and translucency.

CAVOSURFACE MARGINAL DISCOLORATION

Alpha (A) *Visual inspection*
There is no visual evidence of marginal discoloration different from the color of the restorative material and from the color of the adjacent tooth structure.

Bravo (B) *Visual inspection*
There is visual evidence of marginal discoloration at the junction of the tooth structure and the restoration, but the discoloration has not penetrated along the restoration in a pulpal direction.

Charlie (C) *Visual inspection*
There is visual evidence of marginal discoloration at the junction of the tooth structure and the restoration that has penetrated along the restoration in a pulpal direction.

SECONDARY CARIES

Alpha (A) *Visual inspection*
The restoration is a continuation of existing anatomic form adjacent to the restoration.

Bravo (B) *Visual inspection*
There is visual evidence of dark keep discoloration adjacent to the restoration (but not directly associated with cavosurface margins).

ANATOMIC CONTOUR

Alpha (A) *Visual inspection and explorer*
The restoration is a continuation of existing anatomic form or is slightly flattened. It may be overcontoured. When the side of the explorer is placed tangentially across the restoration, it does not touch two opposing cavosurface line angles at the same time.

Bravo (B) *Visual inspection and explorer*
A surface concavity is evident. When the side of the explorer is placed tangentially across the restoration, it does not touch two opposing cavosurface line angles at the same time, but the dentin or base is not exposed.

Charlie (C) *Visual inspection and explorer*
There is a loss of restorative substance such that a surface concavity is evident and the base and/or dentin is exposed.

MARGINAL INTEGRITY

Alpha (A) *Visual inspection and explorer*
The explorer does not catch when drawn across the surface of the restoration toward the tooth, or, if the explorer does not catch, there is no visible crevice along the periphery of the restoration.

Bravo (B) *Visual inspection and explorer*
The explorer catches and there is visible evidence of a crevice, which the explorer penetrates, indicating that the edge of the restoration does not adapt closely to the tooth structure. The dentin and/or the base is not exposed, and the restoration is not mobile.

Charlie (C) *Explorer*
The explorer penetrates crevice defect extended to the dento-enamel junction.

SURFACE TEXTURE

Alpha (A) *Explorer*
Surface texture similar to polished enamel as determined by means of a sharp explorer.

Bravo (B) *Explorer*
Surface texture gritty or similar to a surface subjects to a white stone or similar to a composite containing supramicron-sized particles.

Charlie (C) *Explorer*
Surface pitting is sufficiently coarse to inhibit the continuous movement of an explorer across the surface.

GROSS FRACTURE

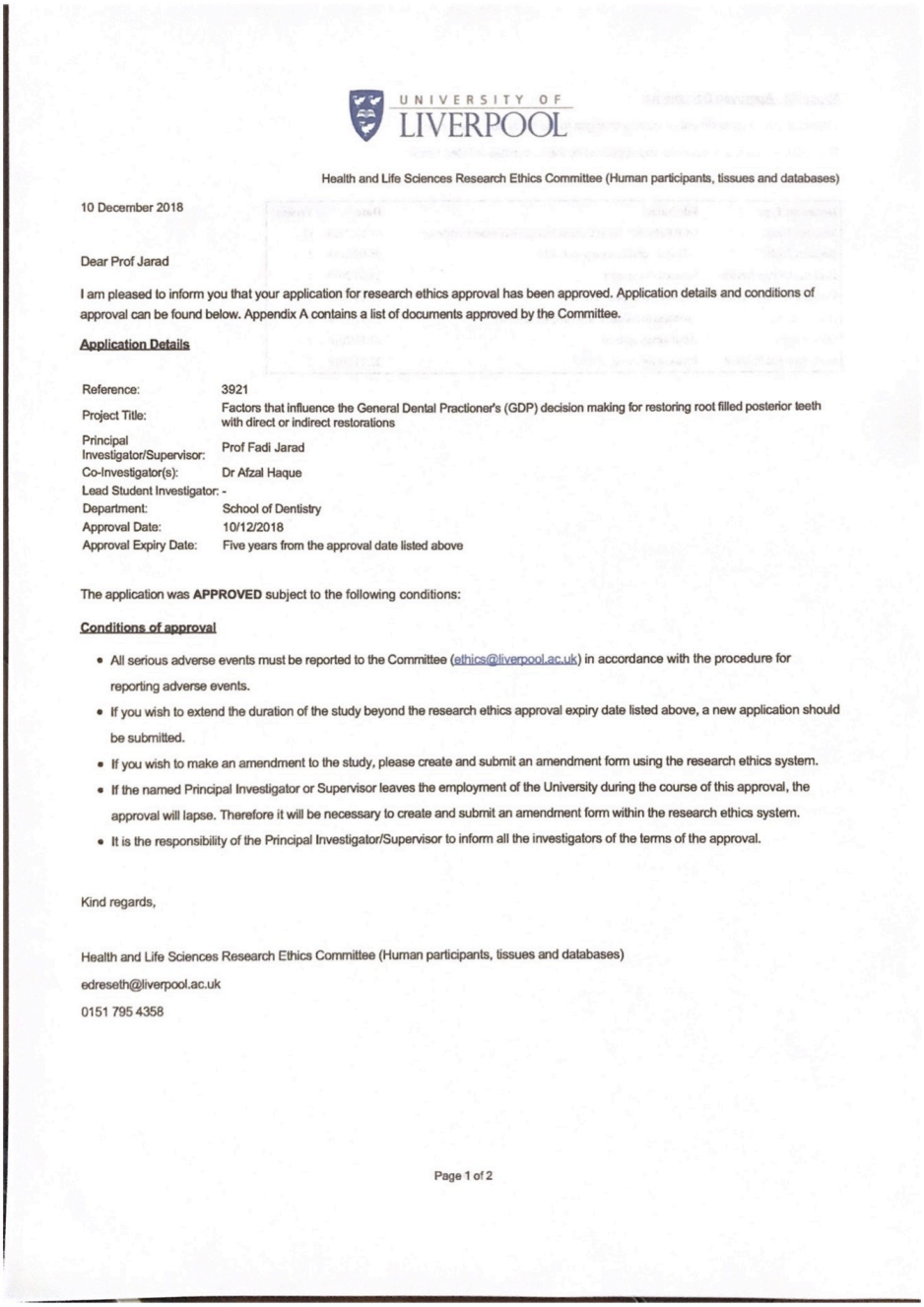
Alpha (A)
Restoration is intact and fully retained.

Bravo (B)
Restoration is partially retained with some portion of the restoration still intact.

Charlie (C)
Restoration is completely missing.

SOURCE Barnes, D.M., Blank, L.W., Gingell, J.C. and Gilner, P.P. : A clinical evaluation of a resin-modified glass ionomer restorative material. *J.A.D.A.*: 126, 1245–1253, 1995.

Appendix 3: Ethics form



UNIVERSITY OF LIVERPOOL

Health and Life Sciences Research Ethics Committee (Human participants, tissues and databases)

10 December 2018

Dear Prof Jarad

I am pleased to inform you that your application for research ethics approval has been approved. Application details and conditions of approval can be found below. Appendix A contains a list of documents approved by the Committee.

Application Details

Reference:	3921
Project Title:	Factors that influence the General Dental Practioner's (GDP) decision making for restoring root filled posterior teeth with direct or indirect restorations
Principal Investigator/Supervisor:	Prof Fadi Jarad
Co-Investigator(s):	Dr Afzal Haque
Lead Student Investigator:	-
Department:	School of Dentistry
Approval Date:	10/12/2018
Approval Expiry Date:	Five years from the approval date listed above

The application was **APPROVED** subject to the following conditions:

Conditions of approval

- All serious adverse events must be reported to the Committee (ethics@liverpool.ac.uk) in accordance with the procedure for reporting adverse events.
- If you wish to extend the duration of the study beyond the research ethics approval expiry date listed above, a new application should be submitted.
- If you wish to make an amendment to the study, please create and submit an amendment form using the research ethics system.
- If the named Principal Investigator or Supervisor leaves the employment of the University during the course of this approval, the approval will lapse. Therefore it will be necessary to create and submit an amendment form within the research ethics system.
- It is the responsibility of the Principal Investigator/Supervisor to inform all the investigators of the terms of the approval.

Kind regards,

Health and Life Sciences Research Ethics Committee (Human participants, tissues and databases)

edreseth@liverpool.ac.uk

0151 795 4358

Page 1 of 2

Appendix 4 Invitation letter

Dear Colleague,

My name is Afzal and I am an Endodontic professional doctorate postgraduate student at the University of Liverpool, School of Dentistry. As part of my PG programme (DDSc in Endodontics), I am carrying out a survey to all general dental practioners (GDPs) in the UK to investigate the factors that impact the GDPs decisions to restore a posterior root filled tooth with a direct or indirect restoration and the time interval after root treatment to place the definitive restoration.

Within the current literature there is limited evidence of the effectiveness of direct restorations over indirect restorations for root filled posterior teeth as well as when to place the definitive restoration. There is no clear guidance within the literature on how and when to restore root filled posterior teeth. In addition, there is no information on current approaches to restoration of root filled posterior teeth in GDPs.

It is hoped that the survey will capture the thoughts, barriers and difficulties encountered by GDPs working in NHS and private practice in the U.K, when deciding to restore root filled posterior teeth.

In order to be able to produce reliable information, it is essential to receive responses from as many GDPs as possible. All GDPs who are registered with the GDC and work in general dental practice in the UK are invited to participate in this survey. Participation is completely voluntary and you are free to withdraw your participation at any time. The survey should take no longer than 20 minutes to complete.

We hope that the results of the study will help to identify any gaps in knowledge, and identify current practices and training needs for GDPs in the UK and ultimately improve the care of patients.
There are no risks associated with participating this this survey. No personal details will be collected and all responses will be anonymised. Identification numbers are provided in order that we may follow up non-responders whilst maintaining anonymity.

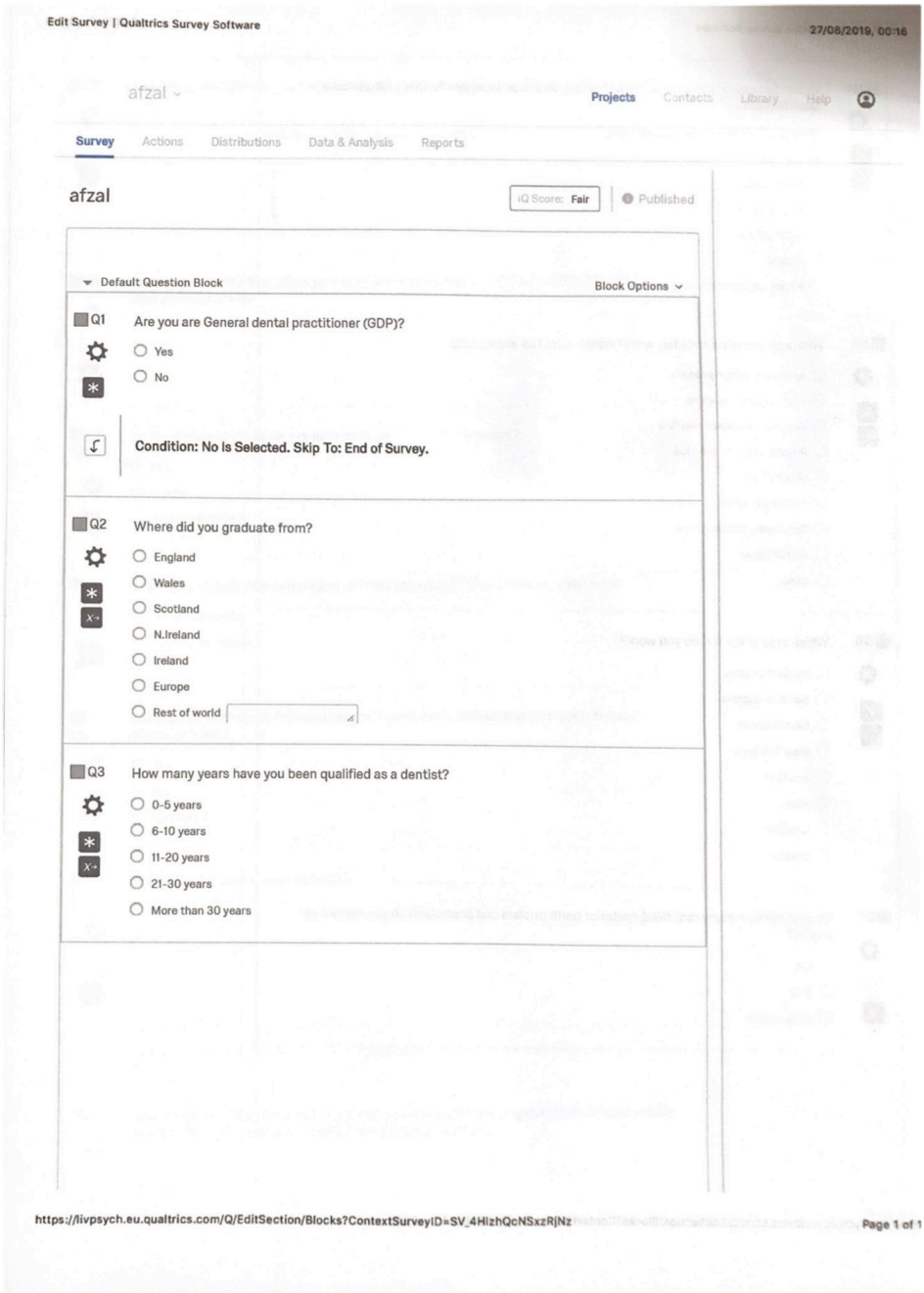
Please answer the following questions based on your current practice.
We would appreciate if you could take your time answering the questions. We are very grateful for your participation

Many thanks for your time

Yours sincerely

Afzal Haque
Doctoral student
University of Liverpool

Appendix 5: Survey to GDPs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afzal
Projects
Contacts
Library
Help
Survey
Actions
Distributions
Data & Analysis
Reports
afzal
iQ Score: Fair
Published
Default Question Block
Block Options
Q1
Are you are General dental practitioner (GDP)?
Yes
No
Condition: No is Selected. Skip To: End of Survey.
Q2
Where did you graduate from?
England
Wales
Scotland
N.Ireland
Ireland
Europe
Rest of world
Q3
How many years have you been qualified as a dentist?
0-5 years
6-10 years
11-20 years
21-30 years
More than 30 years
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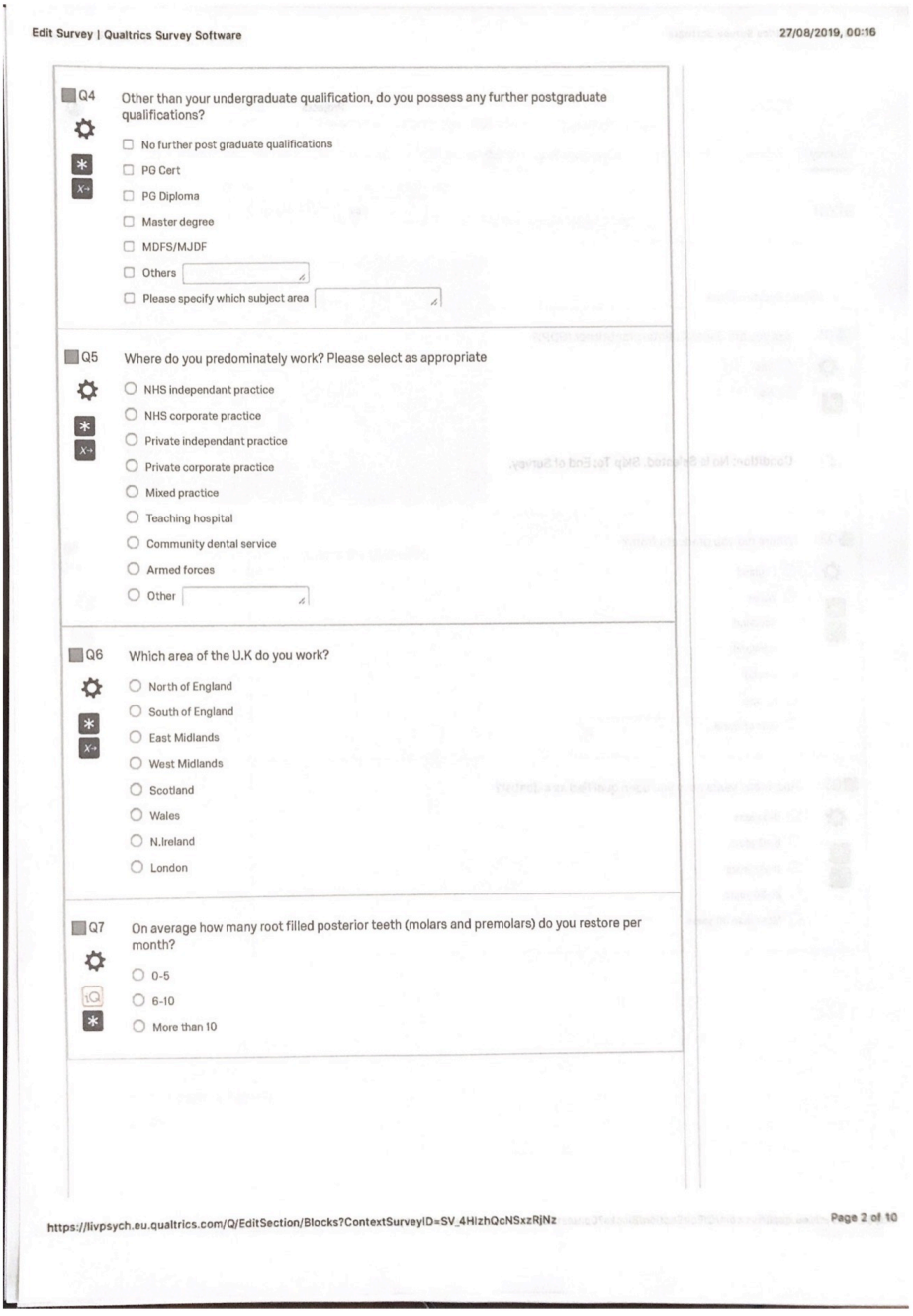
Page 1 of 1



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Q4 Other than your undergraduate qualification, do you possess any further postgraduate qualifications?

- ☐ No further post graduate qualifications
- ☐ PG Cert
- ☐ PG Diploma
- ☐ Master degree
- ☐ MDFS/MJDF
- ☐ Others
- ☐ Please specify which subject area

Q5 Where do you predominately work? Please select as appropriate

- ○ NHS independant practice
- ○ NHS corporate practice
- ○ Private independant practice
- ○ Private corporate practice
- ○ Mixed practice
- ○ Teaching hospital
- ○ Community dental service
- ○ Armed forces
- ○ Other

Q6 Which area of the U.K do you work?

- ○ North of England
- ○ South of England
- ○ East Midlands
- ○ West Midlands
- ○ Scotland
- ○ Wales
- ○ N.Ireland
- ○ London

Q7 On average how many root filled posterior teeth (molars and premolars) do you restore per month?

- ○ 0-5
- ○ 6-10
- ○ More than 10

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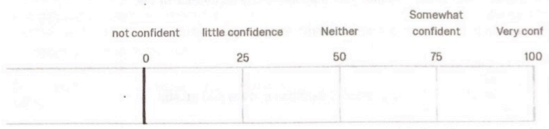
Q8 Overall how confident do you feel when deciding how to restore root filled posterior teeth?



Q9 Please give reasons that affect your confidence when making a decision on restoring root filled posterior teeth?

Q10 Do you restore these teeth predominantly on the NHS or Privately?

- ○ NHS
- ○ Private
- ○ Equal NHS/Private

Q11 What type of restoration would you normally restore root filled posterior teeth with?

- ○ Direct restoration
- ○ Indirect restoration

Q12 Did you feel sufficiently trained as an undergraduate to restore endodontically treated posterior teeth?

- ○ Yes
- ○ No
- ○ Dont know

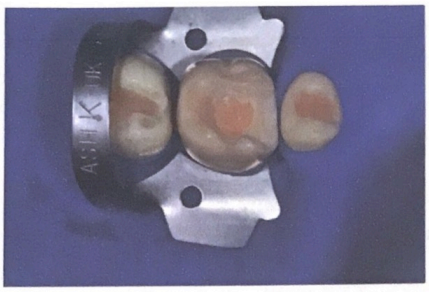
Q13 Please explain your reasoning to Q12

Page Break

You are now going to be read three scenarios with accompanying questions. Please answer the questions as if you were seeing these patients in practice.

Scenario 1

A 21 year old medically fit and well male patient attends your practice for the restoration of the UR6 which has been root treated.
Radiographically the UR6 has a well-obturated root filling to length with no voids and no periapical area.
Previous to RCT the tooth had a sinus and was symptomatic.
Presently, the tooth is asymptomatic.
Oral examination reveals the patient has a minimally restored dentition and low periodontal risk, class 1 occlusion and no tooth surface loss.



Q14

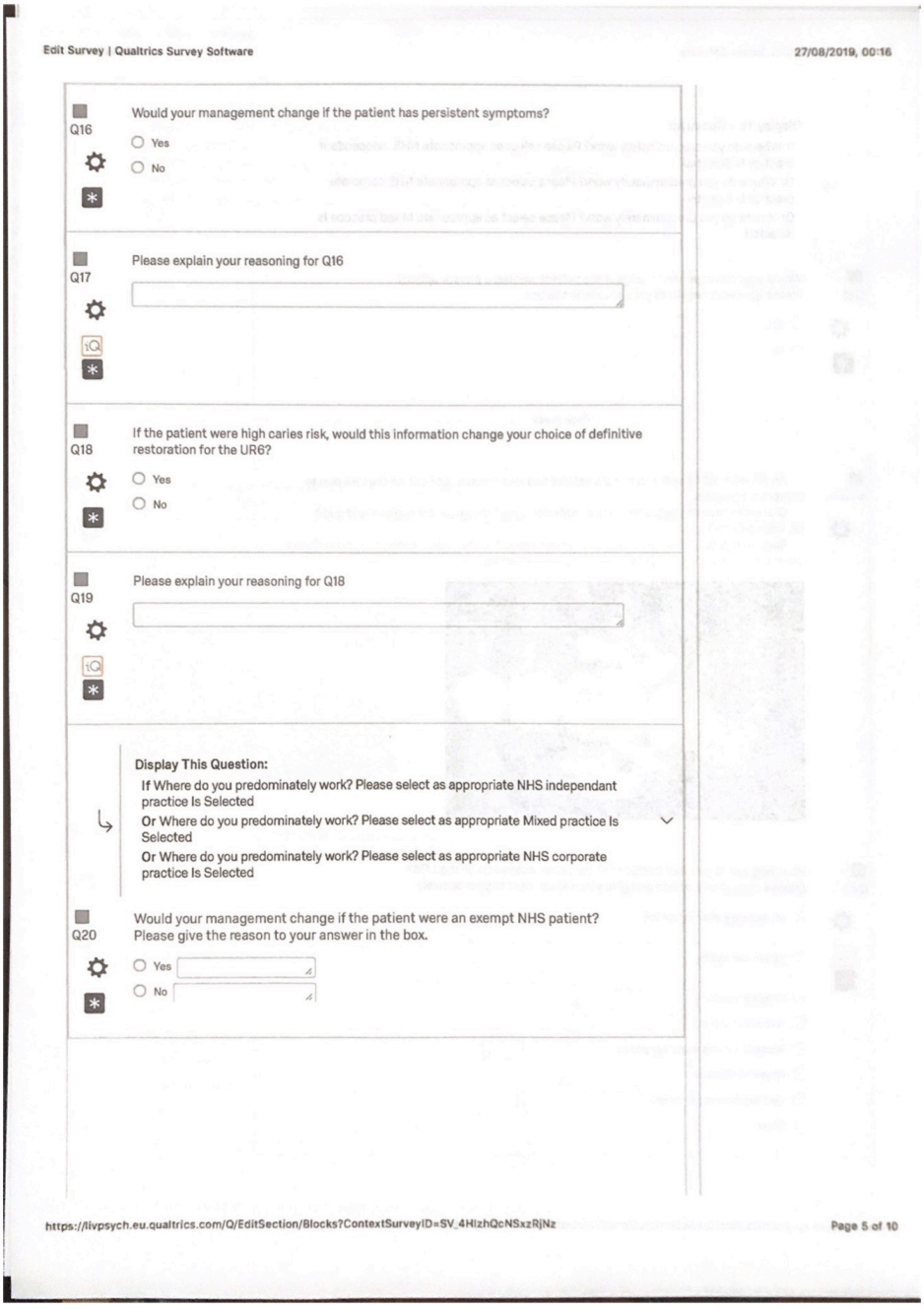
Which restoration would you restore the UR6 with?
(please choose one option)

- ○ Direct Composite
- ○ Direct Amalgam
- ○ Direct Glass ionomer
- ○ Metal ceramic crown
- ○ Ceramic crown
- ○ Metal crown
- ○ Metal onlay
- ○ Ceramic onlay
- ○ Composite onlay
- ○ Other

Q15

When would you place the definitive restoration on the UR6?
(please choose one option)

- ☐ Immediately after obturation
- ☐ Within one month
- ☐ Within 3 months
- ☐ Within 6 months
- ☐ Resolution of signs and symptoms
- ☐ Patient Preference
- ☐ Next available appointment
- ☐ Other



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Q16 Would your management change if the patient has persistent symptoms?

- Yes
- No

Q17 Please explain your reasoning for Q16

Q18 If the patient were high caries risk, would this information change your choice of definitive restoration for the UR6?

- Yes
- No

Q19 Please explain your reasoning for Q18

Display This Question:

If Where do you predominately work? Please select as appropriate NHS independant practice Is Selected

Or Where do you predominately work? Please select as appropriate Mixed practice Is Selected

Or Where do you predominately work? Please select as appropriate NHS corporate practice Is Selected

Q20 Would your management change if the patient were an exempt NHS patient? Please give the reason to your answer in the box.

- Yes
- No

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Display This Question:

If Where do you predominately work? Please select as appropriate NHS independant practice Is Selected
Or Where do you predominately work? Please select as appropriate NHS corporate practice Is Selected
Or Where do you predominately work? Please select as appropriate Mixed practice Is Selected

Q21 Would your management change if the patient wanted a private option?
Please give your reason to your answer in the box

- ○ Yes
- ○ No

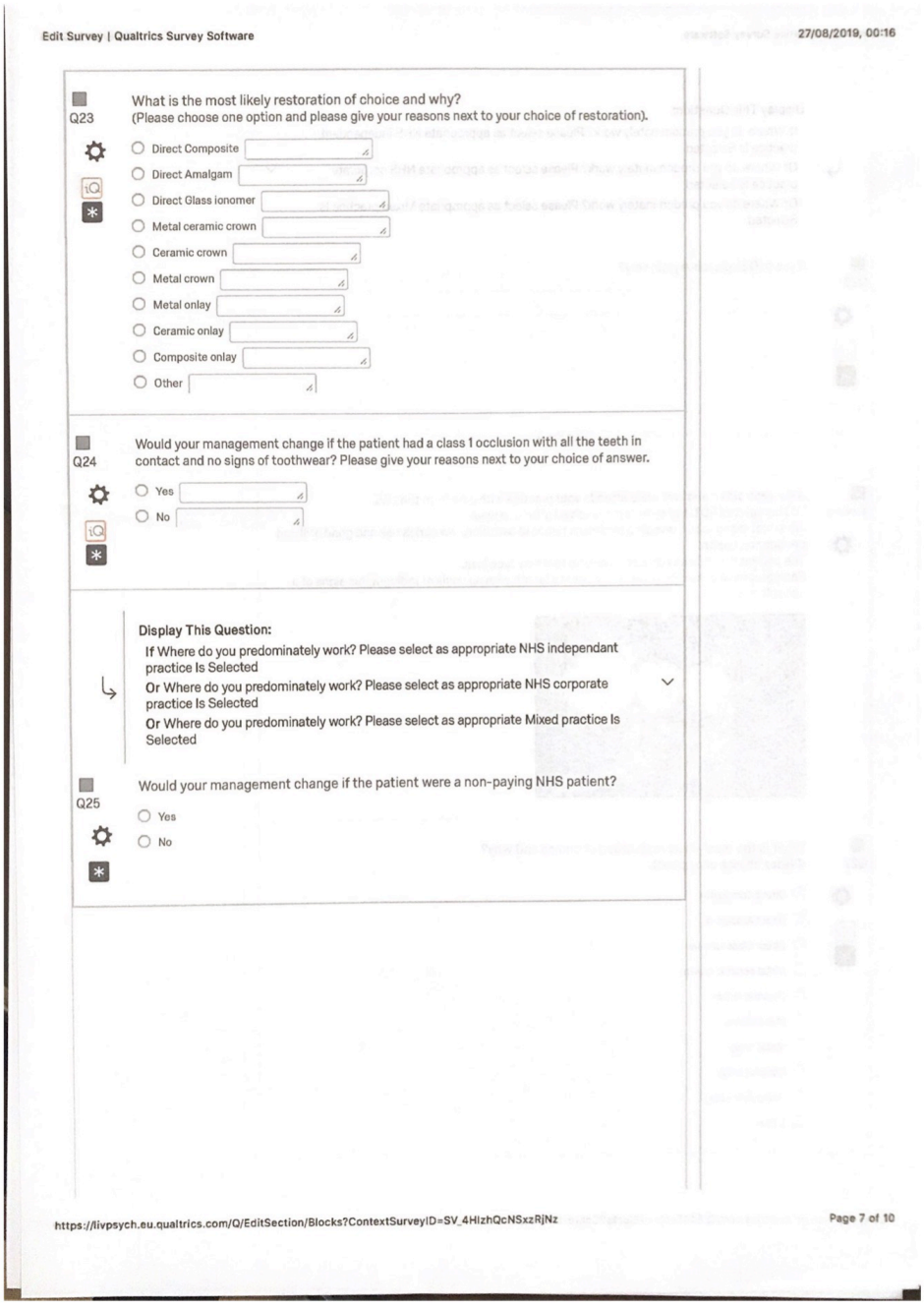
Page Break

Scenario 2

- An 18-year-old fit and well female patient had root canal treatment on the LR6 due to irreversible pulpitis.
- Oral exam reveals the patient has an **anterior open bite**, good oral hygiene and good periodontal health.
- Radiographically the LR6 is well obturated to length in the mesial roots, the obturation is 3mm short in the distal root but has no periapical lesion.

Q22 How long would you wait to place the definitive restoration on the LR6?
(please choose one option and give your reason next to your answer)

- ○ Immediately after obturation
- ○ Within one month
- ○ Within 3 months
- ○ Within 6 months
- ○ Resolution of signs and symptoms
- ○ Patient Preference
- ○ Next available appointment
- ○ Other



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Q23 What is the most likely restoration of choice and why?
(Please choose one option and please give your reasons next to your choice of restoration).

- Direct Composite
- Direct Amalgam
- Direct Glass ionomer
- Metal ceramic crown
- Ceramic crown
- Metal crown
- Metal onlay
- Ceramic onlay
- Composite onlay
- Other

Q24 Would your management change if the patient had a class 1 occlusion with all the teeth in contact and no signs of toothwear? Please give your reasons next to your choice of answer.

- Yes
- No

Display This Question:
If Where do you predominately work? Please select as appropriate NHS independant practice Is Selected
Or Where do you predominately work? Please select as appropriate NHS corporate practice Is Selected
Or Where do you predominately work? Please select as appropriate Mixed practice Is Selected

Q25 Would your management change if the patient were a non-paying NHS patient?

- Yes
- No

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Display This Question:

If Where do you predominately work? Please select as appropriate NHS independant practice Is Selected

Or Where do you predominately work? Please select as appropriate NHS corporate practice Is Selected

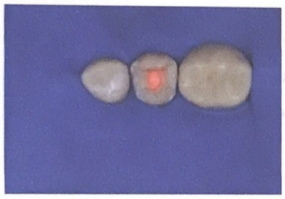
Or Where do you predominately work? Please select as appropriate Mixed practice Is Selected

Q26 If yes to Q25 please explain why?

Page Break

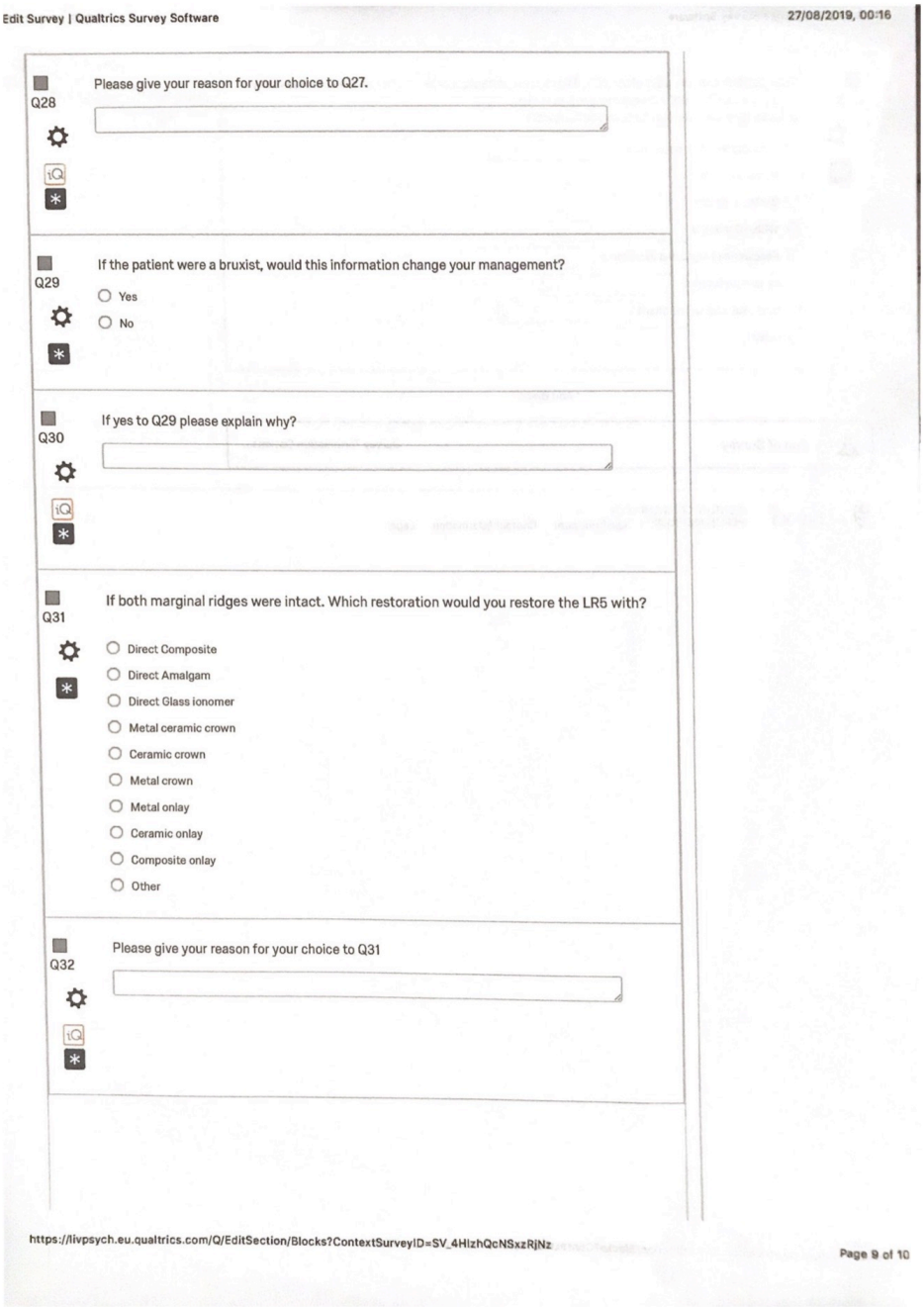
Scenario 3

A 40-year-old fit and well male attends your practice with pain from the LR5.
You completed RCT and symptoms resolved after one week.
Intra-oral examination reveals a minimally restored dentition, low caries risk and good oral and periodontal health.
The patient has a class 1 occlusion and no tooth surface loss.
Radiographically the LR5 is well obturated to length with no voids or radiographic signs of a periapical area



Q27 What is the most likely restoration of choice and why?
(Please choose one option).

- ○ Direct Composite
- ○ Direct Amalgam
- ○ Direct Glass ionomer
- ○ Metal ceramic crown
- ○ Ceramic crown
- ○ Metal crown
- ○ Metal onlay
- ○ Ceramic onlay
- ○ Composite onlay
- ○ Other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Q28
Please give your reason for your choice to Q27.
Q29
If the patient were a bruxist, would this information change your management?
Yes
No
Q30
If yes to Q29 please explain why?
Q31
If both marginal ridges were intact. Which restoration would you restore the LR5 with?
Direct Composite
Direct Amalgam
Direct Glass ionomer
Metal ceramic crown
Ceramic crown
Metal crown
Metal onlay
Ceramic onlay
Composite onlay
Other
Q32
Please give your reason for your choice to Q31
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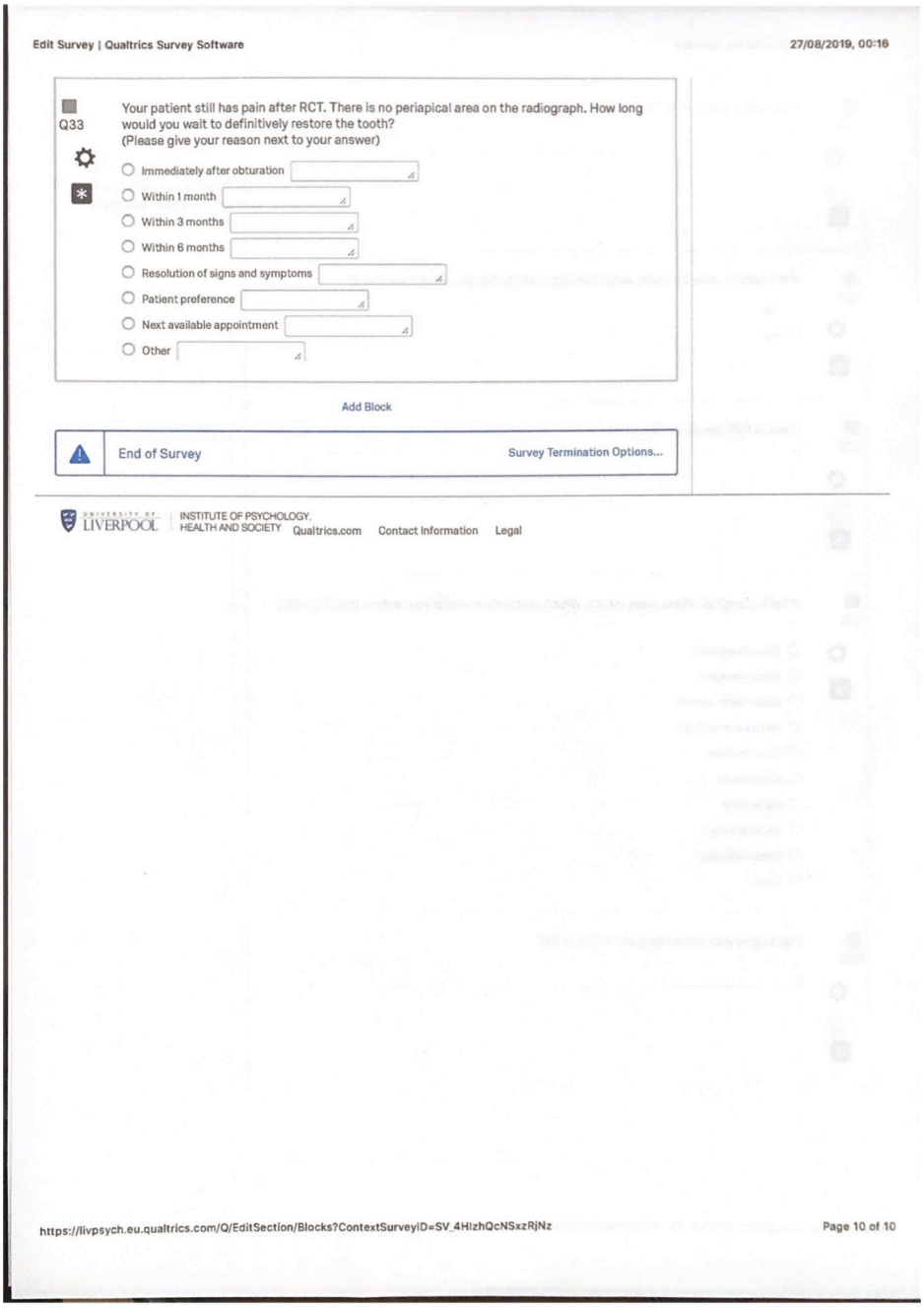

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Q33 Your patient still has pain after RCT. There is no periapical area on the radiograph. How long would you wait to definitively restore the tooth?
(Please give your reason next to your answer)

- Immediately after obturation
- Within 1 month
- Within 3 months
- Within 6 months
- Resolution of signs and symptoms
- Patient preference
- Next available appointment
- Other

Add Block

End of Survey Survey Termination Options...

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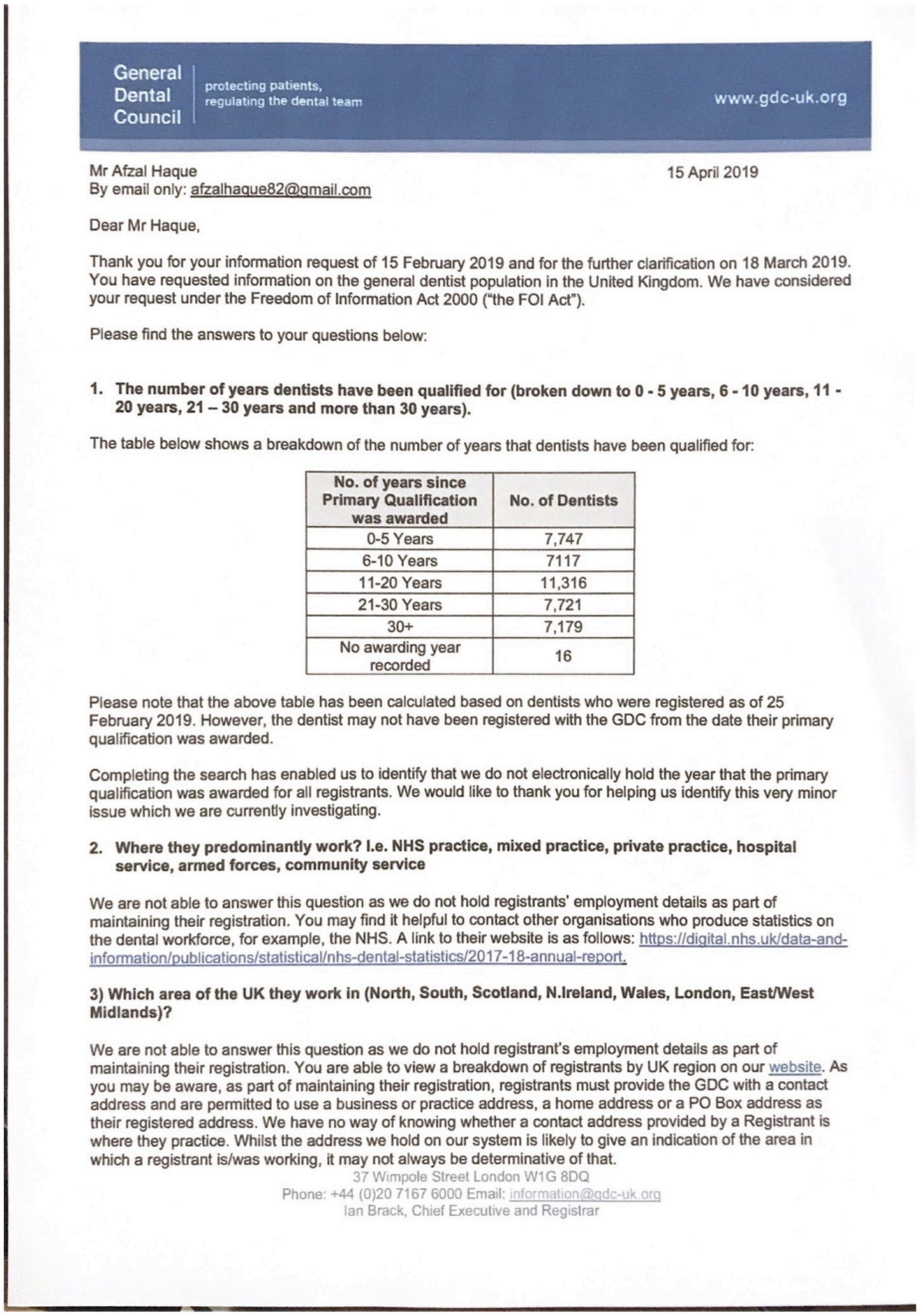
Appendix 6. Freedom of information request GDC.



General Dental Council | protecting patients, regulating the dental team | www.gdc-uk.org

Mr Afzal Haque
By email only: afzalhaque82@gmail.com

15 April 2019

Dear Mr Haque,

Thank you for your information request of 15 February 2019 and for the further clarification on 18 March 2019. You have requested information on the general dentist population in the United Kingdom. We have considered your request under the Freedom of Information Act 2000 ("the FOI Act").

Please find the answers to your questions below:

1. **The number of years dentists have been qualified for (broken down to 0 - 5 years, 6 - 10 years, 11 - 20 years, 21 – 30 years and more than 30 years).**

The table below shows a breakdown of the number of years that dentists have been qualified for:

No. of years since Primary Qualification was awarded	No. of Dentists
0-5 Years	7,747
6-10 Years	7117
11-20 Years	11,316
21-30 Years	7,721
30+	7,179
No awarding year recorded	16

Please note that the above table has been calculated based on dentists who were registered as of 25 February 2019. However, the dentist may not have been registered with the GDC from the date their primary qualification was awarded.

Completing the search has enabled us to identify that we do not electronically hold the year that the primary qualification was awarded for all registrants. We would like to thank you for helping us identify this very minor issue which we are currently investigating.

2. **Where they predominantly work? I.e. NHS practice, mixed practice, private practice, hospital service, armed forces, community service**

We are not able to answer this question as we do not hold registrants' employment details as part of maintaining their registration. You may find it helpful to contact other organisations who produce statistics on the dental workforce, for example, the NHS. A link to their website is as follows: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-dental-statistics/2017-18-annual-report.

3) Which area of the UK they work in (North, South, Scotland, N.Ireland, Wales, London, East/West Midlands)?

We are not able to answer this question as we do not hold registrant's employment details as part of maintaining their registration. You are able to view a breakdown of registrants by UK region on our website. As you may be aware, as part of maintaining their registration, registrants must provide the GDC with a contact address and are permitted to use a business or practice address, a home address or a PO Box address as their registered address. We have no way of knowing whether a contact address provided by a Registrant is where they practice. Whilst the address we hold on our system is likely to give an indication of the area in which a registrant is/was working, it may not always be determinative of that.

37 Wimpole Street London W1G 8DQ
Phone: +44 (0)20 7167 6000 Email: information@gdc-uk.org
Ian Brack, Chief Executive and Registrar

Appendix 7. Poster presentation at ESE 2019

What is the effectiveness of direct and indirect coronal restorations, without posts, for the restoration of root-filled posterior teeth? A systematic review

A Haque, A Boland, J. Greenhalgh, FD Jarad, S Al-Badri
University of Liverpool and Department of Restorative Dentistry, School of Dentistry, University of Liverpool, Liverpool, United Kingdom

UNIVERSITY OF LIVERPOOL

Introduction

- A final restoration must provide a good coronal seal and protect the remaining dental tissue, as well as restore form, aesthetic and occlusal function.
- The main function of a post is the retention of a core or coronal restoration. Meanwhile it is generally assumed that posts do not strengthen teeth, but may even weaken the root due to post space preparation.

Aim

- Aim of this research is to investigate the relative effectiveness of direct and indirect coronal restorations, without posts, for the restoration of root-filled posterior teeth.

Methods

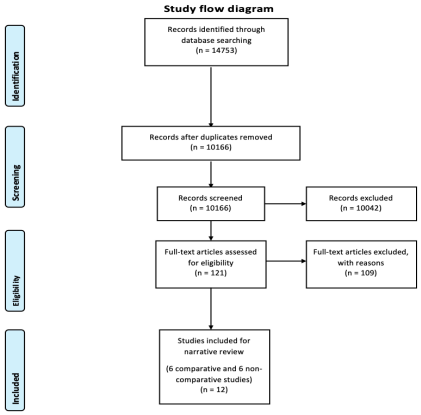
- We searched MEDLINE, PubMed, EMBASE, Scopus, Web of Science and Central from inception to December 2017.
- **Population -** Adults patients over the age of 18, of any gender, who had a root filled permanent mature posterior tooth (premolar or molar teeth), which required a restoration.
- **Intervention -** These included direct restorations e.g. amalgam, composites and glass ionomers and indirect restorations, such as (single coverage crowns e.g. metal, metal-ceramic, all ceramic crowns or other indirect partial restorations, e.g. inlays, onlays, overlays, and endocrowns), all used without posts.
- **Comparator** - The comparators of interest were either direct or indirect restorations in studies with no posts or without comparators
- **Outcome -** Clinical and radiographical failure of the restoration. We used the Down's and Black quality assessment checklist to assess the quality of the included studies.

Search Example

Database: Embase		
Strategy used:		
1	endodontics/ or "root canal therapy"/	27269
2	((Endodontic* or "root canal") adj3 (treat* or therap*)).tw.	9353
3	Tooth, Nonvital/	4893
4	((nonvital* or non-vital* or devital* or pulpless) adj3 (tooth or teeth)).tw.	900
5	1 or 2 or 3 or 4	32825
6	exp Amalgam/	1966
7	composite resins/ or resin cements/	38922
8	Glass Ionomer Cements/	6104
9	exp Dental Restoration/	56374
10	(Amalgam* or Composite* or Resin* or "Glass ionomer").tw.	206174
11	((direct* or permanent* or dental) adj3 restor*).tw.	6241
12	crowns/ or "post and core technique"/	20124
13	exp Inlay/	326
14	(Crown* or Onlay* or Inlay* or Endocrown* or (indirect* adj1 restor*)).tw.	47567
15	"post and core technique*".tw.	22
16	Dental Restoration Failure/	1448
17	or/6-16	301293
18	5 and 17	9952
19	Animals/ not Humans/	1305140
20	18 not 19	9451

Results

- Searches identified 10,166 non-duplicate articles and the study inclusion criteria were applied to 124 articles.
- 12 studies (6 comparative and 6 non-comparative) in the narrative review.
- The majority of the studies were of poor to fair quality and the heterogenous nature of the studies precluded statistical data synthesis.
- One retrospective study compared direct versus indirect restorations for root-filled posterior teeth without posts; however, the robustness of the study results is limited due to the low number of patients in the indirect restoration group (partial gold crown, n=24) compared with the direct restoration group (glass ionomer, n=100; amalgam, n=98 and composite, n=37).
- No other studies were identified that could directly answer the review question. All of the other studies were either non-comparative and examined the effectiveness of one single type of restoration or were comparative and compared direct restorations with other direct restorations; where the studies compared one type of restoration with another, there was always one group that contained restorations with posts.



Conclusions

- There is limited evidence to suggest that direct restorations are more effective than indirect restorations (or vice versa) in root-filled posterior teeth without posts.
- More research into this important area is justified. Paying attention to the amount of tooth structure remaining when restoring root-filled teeth is key to good decision-making

References

Abbott, P. V. (no date) 'Recognition and prevention of failures in clinical dentistry. Endodontics.', *Annals of the Royal Australasian College of Dental Surgeons*, pp. 1991 Oct;11:150–66.

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